# IMPACTS OF OIL AND GAS DEVELOPMENT ON WINTERING GRASSLAND BIRDS AT PADRE ISLAND NATIONAL SEASHORE, TEXAS

A Thesis

by

ARDATH L. LAWSON

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

August 2009

Major Subject: Wildlife and Fisheries Sciences

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Approved by:

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| Co-Chairs of Committee, | R. Douglas Slack |
| | Michael L. Morrison |
| Committee Member, | Fred E. Smeins |
| Head of Department, | Thomas E. Lacher, Jr. |

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## ABSTRACT

Impacts of Oil and Gas Development on Wintering Grassland Birds at Padre Island National Seashore, Texas. (August 2009)

Ardath L. Lawson, B.S., Texas A&M University

Co-Chairs of Advisory Committee: Dr. R. Douglas Slack
Dr. Michael L. Morrison

Padre Island National Seashore provides important habitat for wintering grassland birds, which are declining throughout their breeding range, yet oil and gas development is widespread in the park. My objective was to evaluate the effects of resource extraction on the park's grassland birds and make management recommendations based on my findings.

In January–March 2007 and 2008, I surveyed 5 active, 4 abandoned, and 4 road sites to investigate the relationship between distance from disturbance (well pads, access roads) and bird abundance. I also compared abundance among the 3 site types. At each site I recorded bird numbers and species in 10-m distance bands along all transects (4 transects/well, 2 transects/road), each extending 300 m from the road or pad.

At road sites bird abundance was positively correlated with increased distance from road edge, but I found no linear relationship at active or abandoned well sites. However, mean bird abundance in the first (0–30-m) distance interval of active well transects was less than half that at the second interval, and was the lowest value for all active intervals except the ninth. First-interval abundance at active wells was lower than abundance at any abandoned well interval. Road transects likewise showed low abundance in the initial interval, although unlike at active wells abundance increased steadily with distance from the center of disturbance.

This trend of lower overall numbers at the first interval of active well transects was driven largely by 1 species, the meadowlark. A combination of high noise levels near active well pads (up to 80 dB) and lack of tall vegetation (on average 30% lower

than the 60–90-m interval) from which to sing may have contributed to low numbers of meadowlarks, which were the only birds to sing regularly during my study period.

While most birds appear to be minimally affected by resource extraction at Padre Island, to ensure minimal impacts on sensitive species I recommend: 1) reducing noise at active sites, 2) limiting disturbance to vegetation near pads and roads, 3) maintaining existing perch sites, 4) restoring all vegetation to its pre-extraction condition, 5) limiting road construction.

# DEDICATION

To my mother and father, for instilling in me a love of wild places of all kinds, and above all for imparting an irrepressible sense of curiosity about the world;

And also to Briana, without whom it would have been an entirely different experience.

## NOMENCLATURE

| | |
|---|---|
| PAIS | Padre Island National Seashore |
| AMMO | *Ammodramus* genus sparrow |
| AMPI | American pipit |
| GRSP | Grasshopper sparrow |
| LCSP | Le Conte's sparrow |
| MEAD | Meadowlark |
| SAVS | Savannah sparrow |
| SEWR | Sedge wren |
| YRWA | Yellow-rumped warbler |

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# INTRODUCTION: GRASSLAND BIRDS AND NATURAL RESOURCE EXTRACTION

In the past few decades, populations of grassland birds have declined noticeably throughout their breeding ranges across the continental U.S. (Sauer et al. 2005). Although most evidence implicates habitat changes in the breeding range for this decline, this may be due in part to the large extent to which grassland bird research has focused on breeding season studies. Such emphasis on breeding season ecology occurs despite the fact that most grassland species are migratory and spend at least half the year in migration and on separate wintering grounds (Igl and Ballard 1999). As a result, it is still uncertain what role habitat loss or alteration on the wintering grounds of grassland birds may play in their recent decline.

Southern Texas is known to provide important grassland habitat for wintering birds and is a frequent stopover site for migratory birds (Igl and Ballard 1999). However, much of the native prairie along the Texas coast has been converted to cropland or lost to urban development, so that less than 1% of the original coastal grassland is now considered to be in relatively pristine condition (Smeins et al. 1991). A significant portion of this remaining grassland is located on Padre Island National Seashore (PAIS). Fifteen of the 18 grassland bird species shown by the North American Breeding Bird Survey to have experienced population declines in the past 30 years have been documented at PAIS (Echols 2004), making preservation of island grasslands a priority of avian conservation.

Padre Island has had an extensive history of oil and gas extraction beginning even before the park's founding in 1961. From 1951 to 1981 a total of 70 oil and gas development operations occurred within the boundary of PAIS, consisting of 58 oil and gas wells, 6 pipelines, and 6 seismic exploration operations (National Park Service 2005). Well sites and access roads abandoned within the past few decades have been

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This thesis follows the style of The Journal of Wildlife Management.

restored to some degree as a result of regulations placed on oil companies since the 1970s. The quality of restoration varies noticeably among the park's old well sites, but restoration techniques have evolved and become more rigorous over time. Also, the dynamic environment of the island contributes to the obliteration of abandoned sites by flooding, dune blowouts, and the migration of sand dunes and vegetation over time. Consequently, greatest concern in the park currently revolves around the impacts of ongoing resource extraction operations at active wells.

Although the number of operations has declined overall, as of September 2006 there were still 8 active wells located within the park and 8 more in the planning phases (D. Echols, National Park Service, personal communication). All active wells were located in the northern section of the park, most likely because no park roads extend to the southern section, making access to the south end more expensive and difficult. Because of measures put into place to protect the park's shoreline and wetlands, most drilling has taken place in the interior grasslands of the island, with unknown impacts on the many bird species that inhabit the area during the fall and winter.

In spite of potentially negative effects on local ecosystems, many natural resource extraction operations must take place in ecologically sensitive areas like Padre Island, where steps must be taken to mitigate the detrimental effects of such operations on the surrounding environment. For this reason, it is important to have as nearly complete an understanding as possible of the potential effects of all extraction activities on the flora and fauna of the area. Such impacts include not only the physical disturbance from well pads and the effects of any accidental discharges that may occur in the course of operations, but also the effects of road construction, traffic, human activity, and noise originating both along access roads and at the well pad itself.

To remedy this lack of basic knowledge of the problem, my goal was to evaluate the effects of oil and gas development on the park's grassland birds. More specifically, my objectives were to determine: 1) how distance from disturbance affects numbers of birds, 2) how distance from disturbance affects species composition of birds, 3) how noise levels change with distance and whether this is correlated with changes in numbers or species of birds, and 4) whether numbers, species composition, and species richness of birds differ among active wells and road sites and inactive wells. These results will be used to provide recommendations to park management.

## STUDY AREA

I worked at Padre Island National Seashore (PAIS), located along the Texas Gulf coast (Figure 1). Padre Island is the southernmost in a series of 5 barrier islands that form the Texas coast. It is also the longest barrier island in the U.S., extending 182 km from Corpus Christi south to Brazos Santiago Pass. The island is low-lying and narrow, ranging in width from 0.5 to 7.8 km, and is separated from the mainland by the shallow, hypersaline Laguna Madre. The climate is semi-arid and subtropical, and the island is continuously exposed to strong, moisture-laden gulf winds (Drawe et al. 1981). Most rainfall occurs May–October, with a peak in September. Temperatures are warm throughout the year and only rarely drop below freezing, though numerous cold fronts pass through each winter and some are strong enough to damage cold-sensitive plants (Carls et al. 1995). Hurricanes and tropical storms are infrequent but strongly shape the island's topography and vegetation when they occur. Wildfires are common across the undeveloped portions of the island (Drawe and Kattner 1978).

Padre Island National Seashore extends 106 km, or about 60% of the island's length, with the remainder of the island being largely urbanized and developed for tourism. The northern and southern sections of the park are ecologically distinct, the south being drier with more dunes and tidal flats, and the north containing more wet grasslands and emergent vegetation (Drawe and Kattner 1978). In addition to numerous hectares of wetland, Padre Island contains a large interior grassland component dominated by little bluestem (*Schizachyrium scoparium littorale*), gulfdune paspalum (*Paspalum monostachyum*), cordgrass (*Spartina* spp.), and bushy bluestem (*Adropogon glomeratus*). Where backdune areas merge with interior grassland, sea oat (*Uniola paniculata*) is also common and herbaceous species such as prickly pear (*Opuntia* spp.)

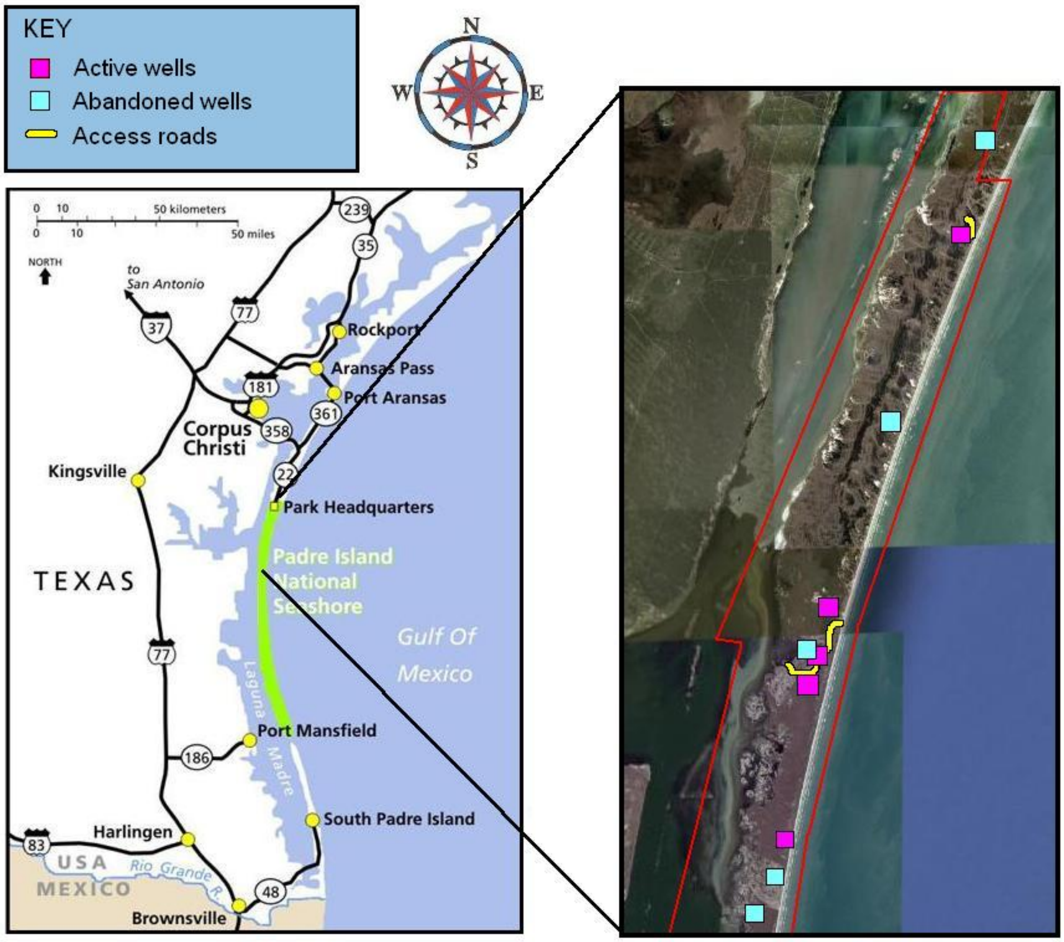



Figure 1. Map of the southern Texas gulf coast, with close-up of study areas on the northern portion of Padre Island National Seashore. Shown are locations of all study sites for 2007–2008, classified as 3 different site types: active wells, abandoned wells, and access roads.

and ground cherry (*Physalis cinerascens*) become more widespread. Wetter areas contain a mixture of grasses, sedges, bulrush (*Scirpus* spp.), and occasionally cattail (*Typha domingensis*).

My study focused exclusively on the section of PAIS extending from the northern boundary to the park's 15-mile marker at Yarborough Pass, because this is where nearly all oil and gas drilling in the park has occurred. Since several wells were sited on tidal mudflats and other ecotypes only marginally used by grassland birds, I confined my study to only those wells located in areas dominated by interior grassland and backdune vegetation.

During my study, weather conditions varied greatly from one field season to the next. Conditions during the 2007 field season averaged slightly cooler than in 2008, with an average high temperature of 17.5 °C the first season and 19.4 °C the second. More significantly, the park also received an above average amount of rainfall in December 2006 (4.38 in, compared to an average of 1.69 in), just prior to the start of my study. As a result, many areas in the northern section of the park that were usually dry or damp grasslands were partially flooded, and large bodies of standing water remained throughout the winter of 2007. In contrast, conditions during the 2008 season were much drier as a result of lower rainfall in 2007. The park received 13 in less in rain in 2007 than 2006, and rainfall for December 2007 was only 0.07 in. Consequently, several semi-permanent water sources were drastically shrunken from the year before or even dried up completely.

# METHODS

## Site Selection

I sampled at 3 different types of sites: active wells, abandoned wells, and roads. Active wells consisted of those that were either being drilled or that were currently in use for pumping and storing natural gas during the study season. Wells in the drilling phase were the most active and were associated with the highest amount of traffic, noise, and human activity.

Five wells were active in the park during the 2-year study period: Wilson, Sprint, Dunn-Peach 1 and 2, and Lemon-Lemonseed. Sprint and Dunn-Peach 1 were completed wells in the pumping stage throughout both the 2007 and 2008 seasons of my study, while Wilson was in the drilling phase for the entire first season and in the pumping stage during the second season. Drilling activity took place at Dunn-Peach 2 during the first few weeks of the 2007 field season but was later shut down. At the start of the second field season in 2008 a new drill rig was erected at Dunn-Peach 2 and drilling resumed for the remainder of the season. The pad for the Lemon-Lemonseed well was also constructed just prior to the start of the second season and drilling occurred for the first few weeks. With the exception of Dunn-Peach 2 in 2007, all wells in the drilling phase had pumping and storage equipment installed after the drill rig was removed, and all continued to be active in this capacity through the end of my study. I was able to survey all of the active grassland wells in the park for my study.

Abandoned wells in my study were those that had been plugged and from which all or most of the structures and machinery had been removed. Because there were >50 abandoned well sites scattered throughout the park and not all had been marked with Universal Transverse Mercator (UTM) coordinates, it was not possible to sample all abandoned wells. Using aerial photographs and descriptions provided by a previous study (Carls et al. 1987), I determined which old wells had likely been sited in grassland areas and attempted to find all such wells for which approximate coordinates were available. However, it proved impossible to locate all disused wells due to incomplete records or obliteration by natural or human-induced changes in topography and vegetation. Consequently, I could include only 4 abandoned wells in my study.

To look at road impacts from resource extraction alone I considered only those roads constructed by the oil companies for well access and I did not include roads created by the park for visitor use or those open only to park personnel. Only 2 major oil and gas access roads were in operation during the course of my study. One of these roads connected the Wilson well to a park road at the north end of the park, while the other, known as the Pan-Am Road, connected 2 different well sites farther down the island and allowed access directly from the beach. These 2 roads were similar in construction, but the newer Wilson well road had been designed with input from the NPS and was intended to minimize impacts to the water flow regime of the area. Both were dirt roads surfaced with a layer of caliche, and both received heavy traffic on a daily basis from trucks and construction vehicles.

**Bird Surveys**

For each well site chosen, the field crew laid out 4 transects of 300 m each extending perpendicular from the center of disturbance. Similarly, for each access road site we laid out 2 300-m transects perpendicular to the sides of the road. We surveyed the Pan-Am Road using 3 separate sites randomly distributed along the grassland portions of the road but no closer to each other than 500 m. The short length of the Wilson well road allowed the placement of only one pair of road transects. All transects at wells and roads were marked visually at both ends and at 10-m intervals using surveyors' tape and flags.

During 6 surveys of each transect, the field crew assigned each bird observation to a distance band perpendicular to the transect (0–9, 10–19, 20–29, 30–40, and >40 m). We visually estimated this as the distance from the center line of the transect to the spot at which the bird was first sighted. Each 300-m transect was additionally divided along its length into 10 intervals of 30 m each, representing increasing distance from the center of disturbance. We recorded numbers and species of birds for each interval. Except for a few species of raptor that search for prey aerially, we did not count birds flying overhead without landing, since it could not be concluded that they were actually using or inhabiting the area covered by the transect.

We conducted all surveys between sunrise and 12:00 during January– March of 2007 and 2008. Surveys took place only on clear to overcast days with no fog or precipitation, with wind speeds ≤29 km/h. During the 2007 field season the survey crew consisted of two people walking approximately 15 m apart and dragging a rope between them to flush skulking birds. A third member was added to the survey crew in 2008 to record data and take noise readings, but the 2 primary observers remained the same for both field seasons.

During each bird survey the crew used a Martel Electronics 320 sound level meter to take noise readings at 0, 150, and 300 m from the well or road. This sound level meter was capable of measuring noise from 30-130 dB in a frequency range of 31.5 Hz to 8 KHz, which we considered adequate for measuring most noise associated with oil and gas extraction activities as reported by other studies (e.g., BLM 2000, La Plata County 2002). Additionally, we took a noise reading whenever we detected a bird, measured at the point along the transect nearest to where the bird flushed. Each noise reading consisted of an average value taken over a 5-second period, rounded to the nearest decibel.

**Vegetation Surveys**

I conducted vegetation sampling using the same line transects used for bird surveys, taking measurements at each 10-m interval along the transects. I used a point-intercept method to record hits of each grass species or forb touching each of every ¼-m interval on a 2-m high range pole. The vegetation characteristics I measured were maximum vegetation height, litter depth, percent grass cover, percent forb cover, and percent bare ground. Percent grass and forb cover were calculated as the percentage of all points at which grass or forbs touched the pole; e.g., if grass touched the range pole at any height at 15 out of 30 measuring points, then percent grass cover would be estimated at 50% for that transect. For the purposes of measuring bare ground, I considered all points to be bare where the base of the range pole did not come in contact with any grass or forb; this did not necessarily preclude the presence of grass or forb "canopy" above the ground. I also measured water depth and percent water cover the first year, when several of my transects were partially flooded.

**Data Analysis**

I used as my focal species 7 grassland passerines: savannah sparrow (*Passerculus sandwichensis*, SAVS), grasshopper sparrow (*Ammodramus savannarum*, GRSP), Le Conte's Sparrow (*Ammodramus leconteii*, LCSP), sedge wren (*Cistithorus latensis*, SEWR), American pipit (*Anthus rubescens*, AMPI), yellow-rumped warbler (*Dendroica coronata*, YRWA), and meadowlark (*Sturnella magna* or *S. neglecta*, MEAD). Because of the extremely brief viewing time I had of most sparrows that I flushed, I could not always assign a species (either grasshopper or Le Conte's) to all sparrows of the genus *Ammodramus* that I observed. Since these unidentified sparrows constituted about half of all observed *Ammodramus*, I assigned these a separate category (AMMO) for the purposes of data analysis rather than omit them entirely. Including this generic category, these 8 passerine groups accounted for most of the birds I observed during both field seasons, except for yellow-rumped warbler which I sighted only during 2007. Although I also recorded other grassland species such as northern bobwhite (*Colinus virginianus*) and loggerhead shrikes (*Lanius ludovicianus*), I excluded these birds from my analyses based on very low numbers of observations ($n \leq 3$).

For all analyses I used an index of bird abundance calculated by taking the mean of all bird sightings across each of my 6 transect visits. I assumed detectability to be virtually the same across all sites since birds along the center of the transect were equally likely to be flushed by rope dragging regardless of site type or vegetation differences, while birds beyond the rope could only be located when perching or flying, which were also easily observed at any location. Although detectability of birds certainly declined with distance from the transect's center, there was no reason to believe that this decrease in detectability did not affect all sites similarly. Differences in noise levels did not change detectability of birds since all birds were located visually.

I estimated species richness (S) and compared diversity (H) among active, abandoned, and road sites using the Shannon-Wiener index (Shannon and Weaver 1963). I used univariate linear regression models (Zar 1996:317–352) to test whether bird abundances and vegetation parameters changed with increasing distance from well pads or roads. I used a 95% confidence interval to detect differences in noise levels (dB) among site types at the beginning, middle, and end of all transects. To test for differences in abundance and vegetation among my three site types I ran analyses of variance (ANOVA) using Tukey's highly significant difference test to determine significance (Zar 1996:235–276). I also computed means and standard errors for each vegetation parameter and for noise levels. Because trends in bird abundance and noise levels did not differ significantly ($P < 0.05$) across field seasons I pooled data from both 2007 and 2008 for my analyses. All statistical analyses were performed using the SPSS statistical package (Version 16.0, Norusis 1994).

# RESULTS

## Summary Statistics

Total numbers of all grassland birds sighted (Table 1) was comparable across years ($n$ = 1221 in 2007, $n$ = 1195 in 2008), as were abundances for most species. However, there were some fluctuations in abundance in a few species, and species composition varied slightly from 1 year to the next. There were almost twice as many raptor sightings in 2007 as in 2008 ($n$ = 69 versus $n$ = 37), and some non-target species such as Wilson's snipe (*Gallinago delicata*) and mourning dove (*Zenaida macroura*) were nearly absent from 2008 surveys in spite of being fairly common in 2007. Two other species, loggerhead shrike and great-tailed grackle (*Quiscalus mexicanus*), were found only in 2008.

Numbers of sightings of target species alone (Table 2) was also similar between the 2007 and 2008 field seasons ($n$ = 918 versus $n$ = 1044). Although total numbers of birds sighted remained similar across years, numbers of individuals within species differed markedly in some cases. Grasshopper sparrows accounted for a much larger number of sightings in 2008 ($n$ = 53) than in 2007 ($n$ = 18), as did sedge wrens ($n$ = 85 in 2008 versus $n$ = 13 in 2007). Yellow-rumped warblers were entirely absent from surveys in 2008, though they accounted for 14 sightings in 2007.

Savannah sparrows made up over half (≥57%) of the birds sighted in either field season (Table 3). Meadowlarks were the next most common species, accounting for 22% of all sightings during either year. Each of the other target species accounted for ≤10% of all sightings. Grasshopper sparrows constituted a higher proportion of all birds observed at road sites than they did at either type of well site, making up an average of 7% of all species at road sites compared to 3% at active sites and 2.5% at abandoned sites. Le Conte's sparrows showed a similar pattern, accounting for an average of 8% at road sites, 3.5% at active sites, and 2.5% at road sites. Savannah sparrows were sighted in proportionately greater numbers at abandoned (64%) than active or road sites (each 57%). Though much less common, sedge wrens likewise made up a higher proportion of

Table 1. Total sightings (*n*) of all grassland birds with mean abundances (birds/transect/visit) ± standard error (SE) for 3 site types (active wells, abandoned wells, access roads), 2007–2008.

| | **2007** | | | | **2008** | | | |
|---|---|---|---|---|---|---|---|---|
| | **n** | **Abundance ± SE** | | | **n** | **Abundance ± SE** | | |
| **Species** | | **Active** | **Abandoned** | **Road** | | **Active** | **Abandoned** | **Road** |
| Turkey vulture | 7 | 0.03±0.01 | 0.04±0.02 | 0.00±0.00 | 4 | 0.01±0.01 | 0.03±0.02 | 0.02±0.02 |
| Northern harrier | 22 | 0.17±0.04 | 0.03±0.02 | 0.12±0.06 | 13 | 0.04±0.02 | 0.05±0.02 | 0.06±0.04 |
| White-tailed hawk | 29 | 0.24±0.10 | 0.07±0.02 | 0.10±0.40 | 14 | 0.01±0.01 | 0.05±0.02 | 0.10±0.50 |
| Crested caracara | 5 | 0.01±0.01 | 0.04±0.02 | 0.00±0.00 | 4 | 0.01±0.01 | 0.02±0.01 | 0.00±0.00 |
| American kestrel | 3 | 0.04±0.02 | 0.00±0.00 | 0.00±0.00 | 0 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 |
| Merlin | 1 | 0.01±0.01 | 0.00±0.00 | 0.00±0.00 | 2 | 0.01±0.01 | 0.01±0.01 | 0.00±0.00 |
| Peregrine falcon | 2 | 0.03±0.02 | 0.00±0.00 | 0.00±0.00 | 0 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 |
| Northern bobwhite | 3 | 0.03±0.02 | 0.00±0.00 | 0.00±0.00 | 2 | 0.00±0.00 | 0.00±0.00 | 0.04±0.04 |
| Wilson's snipe | 8 | 0.04±0.02 | 0.05±0.02 | 0.00±0.00 | 1 | 0.00±0.00 | 0.01±0.01 | 0.00±0.00 |
| Mourning dove | 156 | 1.9±0.95 | 0.12±0.05 | 0.00±0.00 | 2 | 0.01±0.01 | 0.00±0.00 | 0.00±0.00 |
| Horned lark | 1 | 0.00±0.00 | 0.01±0.01 | 0.00±0.00 | 0 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 |
| Sedge wren | 13 | 0.03±0.02 | 0.12±0.03 | 0.00±0.00 | 85 | 0.29±0.04 | 0.46±0.05 | 0.17±0.05 |

Table 1. Continued.

| | 2007 | | | | 2008 | | | |
|---|---|---|---|---|---|---|---|---|
| | n | Abundance ± SE | | | n | Abundance ± SE | | |
| **Species** | | **Active** | **Abandoned** | **Road** | | **Active** | **Abandoned** | **Road** |
| American robin | 2 | 0.03±0.02 | 0.00±0.00 | 0.00±0.00 | 0 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 |
| American pipit | 19 | 0.06±0.03 | 0.11±0.04 | 0.08±0.04 | 16 | 0.05±0.02 | 0.07±0.03 | 0.06±0.04 |
| Loggerhead shrike | 0 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 3 | 0.01±0.01 | 0.02±0.01 | 0.00±0.00 |
| Yellow-rumped warbler | 19 | 0.16±0.08 | 0.07±0.03 | 0.00±0.00 | 0 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 |
| Vesper sparrow | 7 | 0.04±0.03 | 0.01±0.01 | 0.02±0.02 | 1 | 0.00±0.00 | 0.00±0.00 | 0.02±0.02 |
| Savannah sparrow | 579 | 2.59±0.50 | 3.11±0.34 | 1.75±0.37 | 597 | 2.15±0.23 | 2.71±0.26 | 2.00±0.34 |
| Grasshopper sparrow | 18 | 0.05±0.02 | 0.06±0.02 | 0.17±0.05 | 53 | 0.21±0.04 | 0.16±0.04 | 0.29±0.07 |
| Le Conte's sparrow | 35 | 0.17±0.04 | 0.16±0.04 | 0.14±0.05 | 34 | 0.13±0.03 | 0.11±0.03 | 0.29±0.07 |
| Swamp sparrow | 1 | 0.01±0.01 | 0.00±0.00 | 0.00±0.00 | 0 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 |
| Unknown *Ammodramus* | 40 | 0.21±0.05 | 0.15±0.04 | 0.21±0.06 | 30 | 0.18±0.04 | 0.05±0.02 | 0.08±0.04 |
| Unknown sparrow | 32 | 0.12±0.04 | 0.18±0.04 | 0.12±0.05 | 29 | 0.09±0.03 | 0.11±0.04 | 0.19±0.06 |
| Meadowlark | 206 | 1.21±0.22 | 0.83±0.12 | 0.76±0.21 | 244 | 0.88±0.13 | 0.99±0.17 | 0.67±0.17 |
| Great-tailed grackle | 0 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 48 | 0.41±0.25 | 0.00±0.00 | 0.00±0.00 |

Table 2. Total sightings of target passerine species at active, abandoned, and road sites, 2007–08. Target species are savannah sparrow (SAVS), grasshopper sparrow (GRSP), Le Conte's Sparrow (LCSP), sedge wren (SEWR), American pipit (AMPI), yellow-rumped warbler (YRWA), and meadowlark (MEAD), plus *Ammodramus* genus sparrows (AMMO).

| | SAVS | GRSP | LCSP | AMMO | YRWA | SEWR | AMPI | MEAD | Total |
|---|---|---|---|---|---|---|---|---|---|
| **2007** | 579 | 18 | 35 | 40 | 19 | 13 | 8 | 206 | 918 |
| Active | 199 | 4 | 13 | 16 | 12 | 2 | 2 | 94 | 342 |
| Abandoned | 295 | 5 | 15 | 14 | 7 | 11 | 5 | 80 | 432 |
| Road | 85 | 9 | 7 | 10 | 0 | 0 | 1 | 32 | 144 |
| **2008** | 600 | 53 | 37 | 30 | 0 | 85 | 14 | 225 | 1044 |
| Active | 251 | 24 | 14 | 21 | 0 | 34 | 6 | 102 | 452 |
| Abandoned | 251 | 15 | 10 | 5 | 0 | 43 | 5 | 92 | 421 |
| Road | 98 | 14 | 20 | 4 | 0 | 8 | 3 | 31 | 178 |

Table 3. Target passerine species as proportion of total sightings at active, abandoned, and road sites, 2007–08. Target species are savannah sparrow (SAVS), grasshopper sparrow (GRSP), Le Conte's Sparrow (LCSP), sedge wren (SEWR), American pipit (AMPI), yellow-rumped warbler (YRWA), and meadowlark (MEAD), plus *Ammodramus* genus sparrows (AMMO).

| | **SAVS** | **GRSP** | **LCSP** | **AMMO** | **YRWA** | **SEWR** | **AMPI** | **MEAD** |
|---|---|---|---|---|---|---|---|---|
| **2007** | 0.63 | 0.02 | 0.04 | 0.04 | 0.02 | 0.01 | 0.01 | 0.22 |
| Active | 0.58 | 0.01 | 0.04 | 0.05 | 0.04 | 0.01 | 0.01 | 0.27 |
| Abandoned | 0.68 | 0.01 | 0.03 | 0.03 | 0.02 | 0.03 | 0.01 | 0.19 |
| Road | 0.59 | 0.06 | 0.05 | 0.07 | 0.00 | 0.00 | 0.01 | 0.22 |
| **2008** | 0.57 | 0.05 | 0.04 | 0.03 | 0.00 | 0.08 | 0.01 | 0.22 |
| Active | 0.56 | 0.05 | 0.03 | 0.05 | 0.00 | 0.08 | 0.01 | 0.23 |
| Abandoned | 0.60 | 0.04 | 0.02 | 0.01 | 0.00 | 0.10 | 0.01 | 0.22 |
| Road | 0.55 | 0.08 | 0.11 | 0.02 | 0.00 | 0.04 | 0.02 | 0.17 |

all bird species at abandoned sites (6.5%) than at active (4.5%) and road sites (2%). Meadowlarks constituted nearly the same proportion of total sightings at active (23%) and abandoned well sites and a slightly smaller proportion (17%) along road transects. Of all target species, only the yellow-rumped warbler made up a greater proportion of sightings at active wells (4%) than at the other 2 other site types (2% at abandoned wells and 0% at roads).

Numbers of species observed ranged from 5–10 species per site, the lowest number occurring at the active Lemon-Lemonseed well and the highest at the abandoned Louis-Dreyfuss well site. However, species richness (S) was virtually indistinguishable across site types: S = 11 for active and abandoned wells alike, and S = 10 at roads. Active wells also attracted large numbers (flocks of ≥10 individuals) of 2 non-grassland species, great-tailed grackles and mourning doves, that were not present at either abandoned wells or road sites.

Shannon-Wiener diversity indices likewise showed little difference among site types. The most distinct difference occurred in the first field season, when active site diversity (H) was greatest at H = 1.63, followed by road sites (H = 1.53) and abandoned sites (H = 1.22). The second year the differences were somewhat less pronounced, with road site diversity highest (H = 1.60), and active sites (H = 1.40) and abandoned sites (H = 1.44) nearly identical. Combining both years, road sites had the greatest diversity by a narrow margin (H = 1.72), and active sites (H = 1.67) were still slightly more diverse than abandoned sites (H = 1.48).

**Avian Analyses**

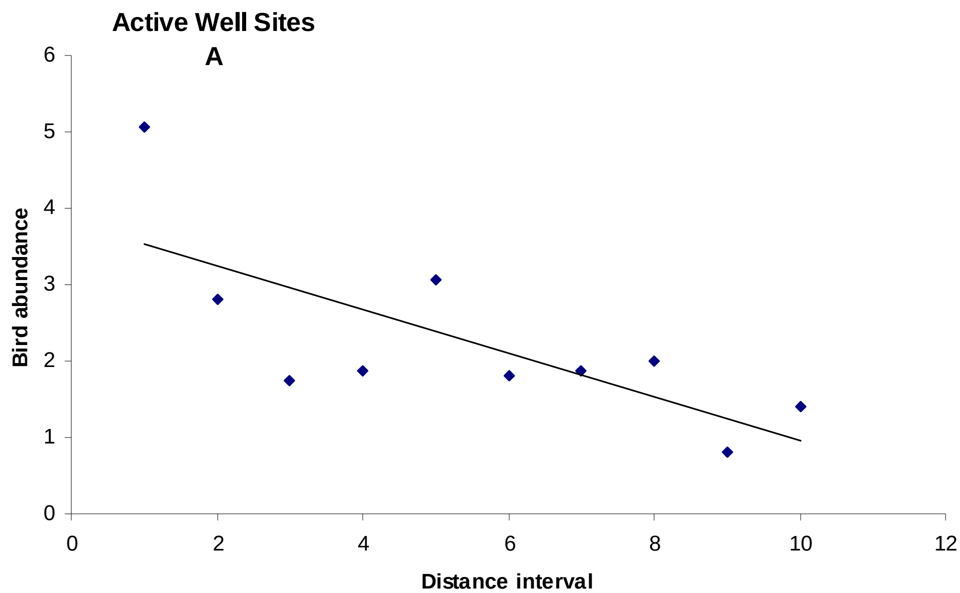
The relationship between distance and bird abundance at active wells differed slightly depending on how it was analyzed (Figure 2). On a single visit to 1 active well site in 2007, I sighted large numbers of birds (>20) in the 0–30-m distance band, primarily savannah sparrows. After this visit I never again observed such high numbers of birds, ≤5 being sighted during any subsequent visit. Including the >20 sparrows from the first visit, my regression model showed a significant but weak linear relationship ($R^2$

= 0.041, $P$ = 0.010) between distance and abundance, with abundance highest close to the well pad and declining with distance. Excluding this large flock from the analysis, no linear relationship appeared ($R^2$ = 0.00, $P$ = 0.883).

Linear regression models showed no clear linear relationship ($R^2$ = 0.004, $P$ = 0.204) between distance from the well pad and bird abundance at abandoned sites (Figure 3). Bird abundance also showed a significant increase ($R^2$ = 0.625, $P$ = 0.006) with increasing distance from roads (Figure 4).

Mean bird abundance did not differ significantly among active, abandoned, and road sites (Figure 5). I further divided active wells into 2 subcategories, actively drilling well sites and pumping station sites where drilling was no longer taking place (Figure 6). Again, no significant difference among the site types was detected, but mean abundance was slightly lower at drilling wells (3.7 ± 3.1) than at either pumping (4.9 ± 4.7) or abandoned (4.4 ± 3.5) sites, and was comparable to road site abundance (3.6 ± 3.1). Bird abundance at each distance interval was also similar among the 3 site types (Table 4) and did not differ significantly. In spite of this overall similarity in abundance across sites, bird numbers did appear to be slightly lower in the distance interval closest to active well pads. Although not significantly different, mean abundance at the first interval of active wells transects (1.18 ± 1.82) was less than half that at the second interval (2.85 ± 2.51), and was the lowest value for all active intervals except the ninth (1.1 ± 1.66). First-interval abundance at active wells was also lower than abundance at any abandoned well interval. Road transects also showed low abundance in the initial interval (1.0 ± 1.79), although unlike at active wells abundance increased steadily with distance from the center of disturbance.

When broken down by sightings of individual species (Table 5), it appeared that the trend of lower overall numbers at the first interval of active well transects was driven largely by 2 species, meadowlarks and sedge wrens. Meadowlark abundance at this first interval (x = 0.31 ± 0.79 SD) was 47% less than abundance at the second interval (x = 0.58 ± 1.42 SD) and was lower than at any other active transect distance interval. Though meadowlark abundance at the 0–30 interval of active well sites was similar to



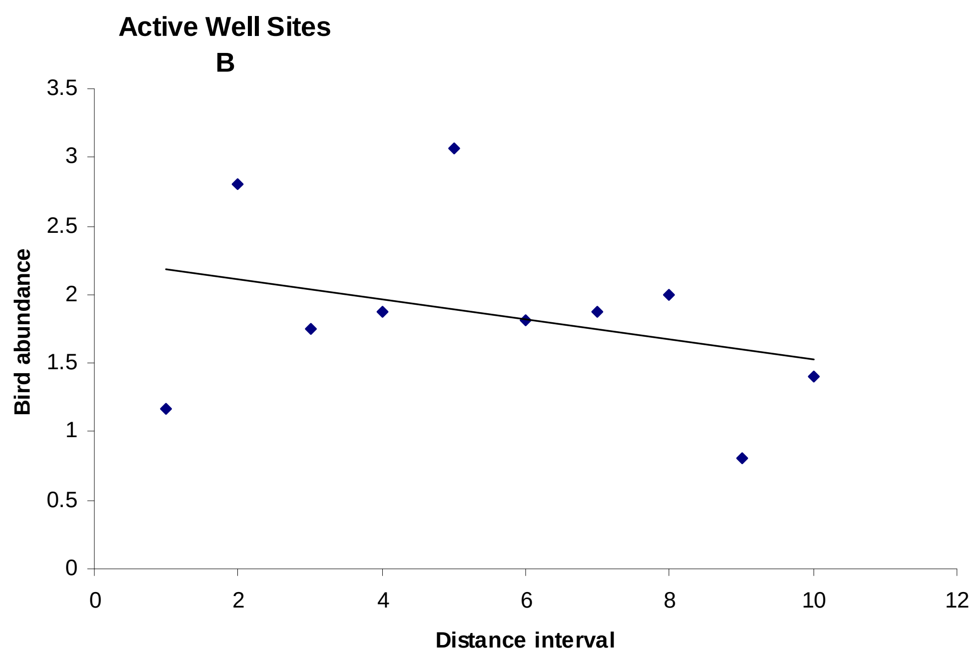




Figure 2. Bird abundance (mean birds/transect/visit) with increasing distance from edge of active well pads, 2007–08. Diagram A ($R^2 = 0.041$, $P = 0.010$) includes flock of ≥20 sparrows only sighted once, during Visit 1. Diagram B ($R^2 = 0.00$, $P = 0.883$) excludes this flock.

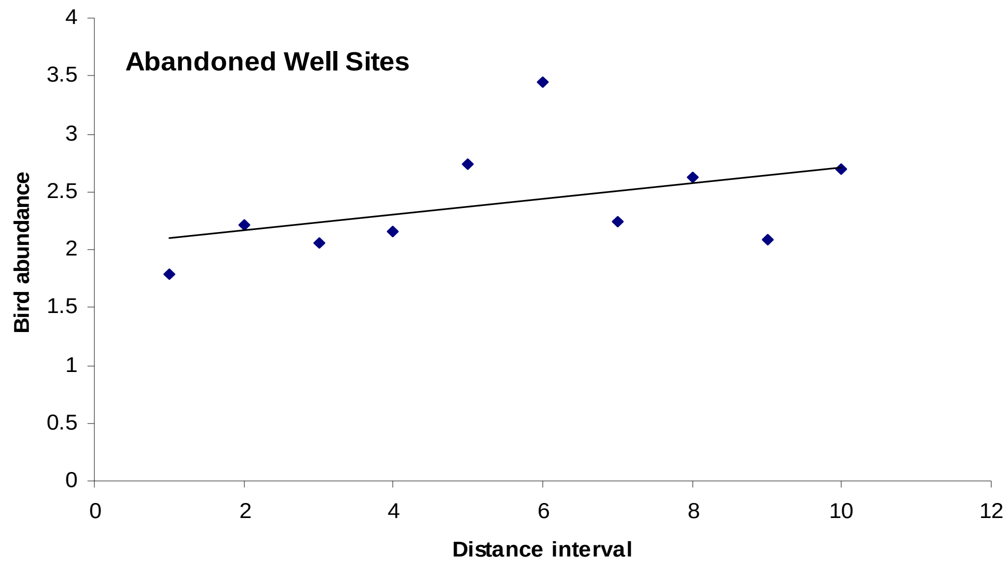



Figure 3. Bird abundance (mean birds/transect/visit) with increasing distance from edge of abandoned well pads, 2007–08. $R^2 = 0.004$, $P = 0.204$.

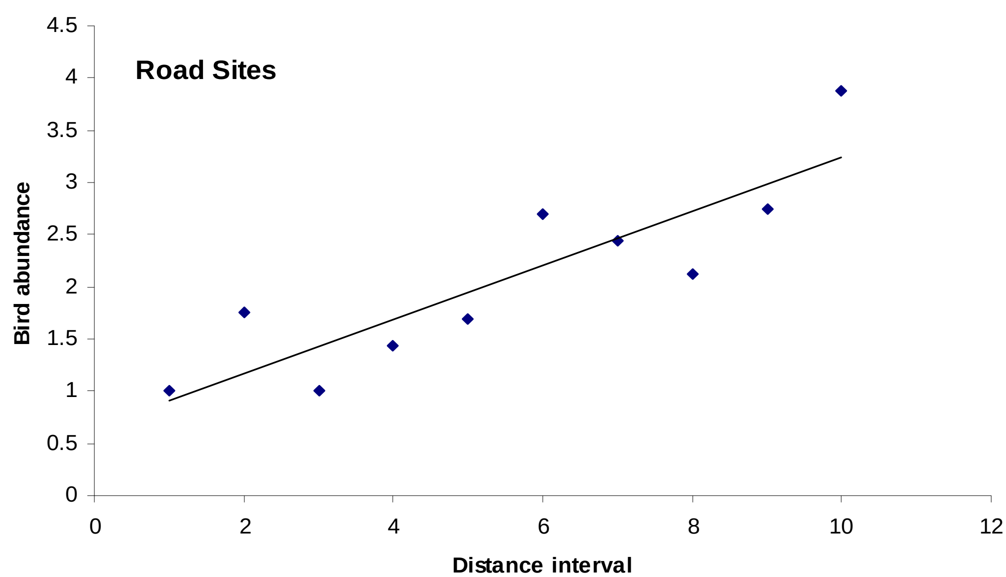



Figure 4. Bird abundance (mean birds/transect/visit) with increasing distance from edge of access roads, 2007–08. $R^2 = 0.625$, $P = 0.006$.

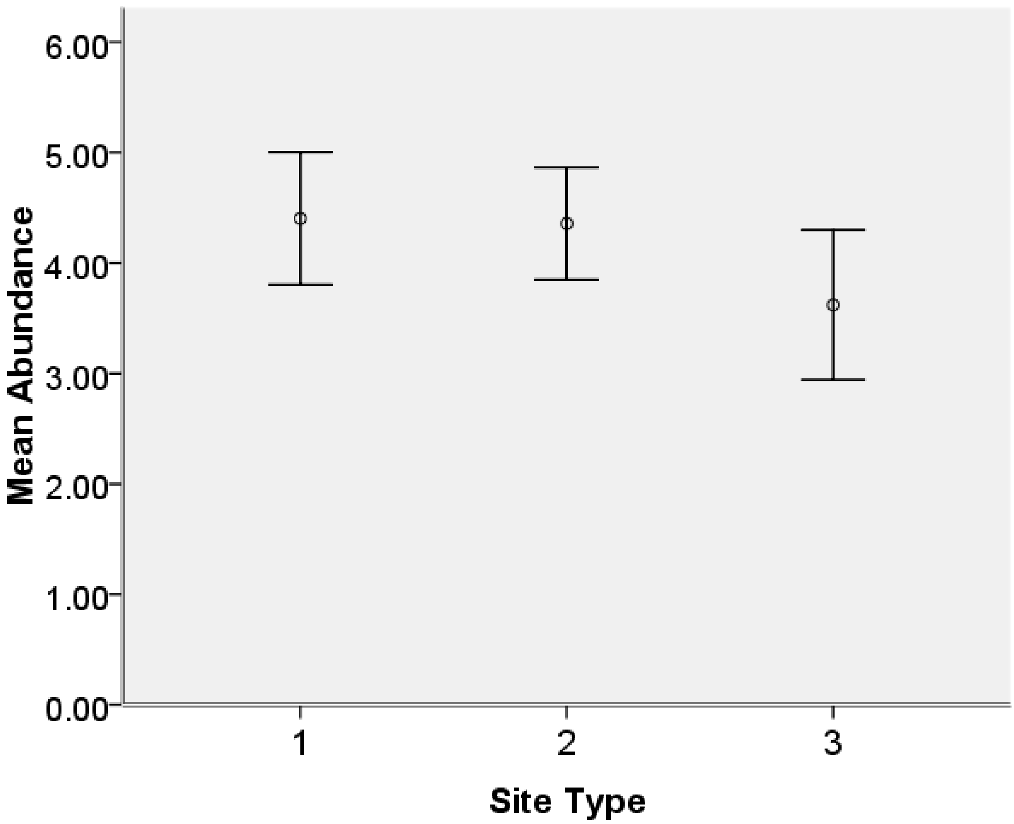



Figure 5. 95% confidence intervals for mean bird abundance (birds/site/visit) 2007–08 at (1) active (n = 5), (2) abandoned (n = 5), and (3) road (n = 4) sites.

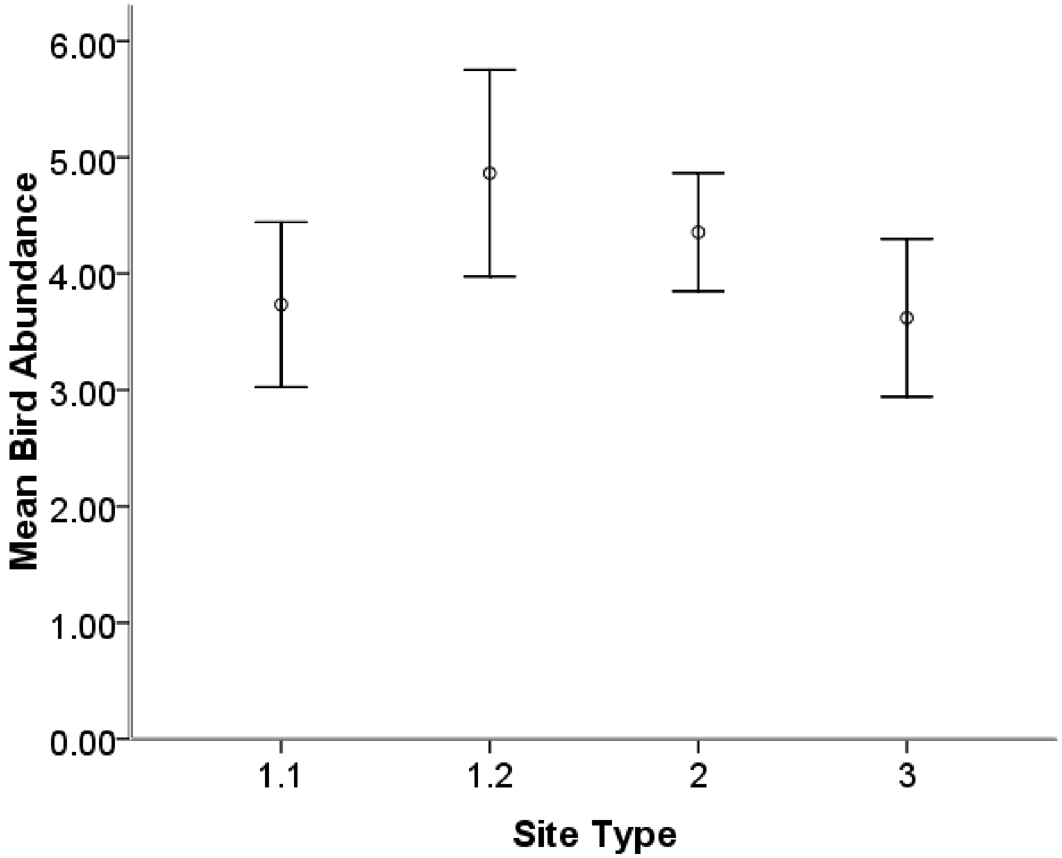



Figure 6. 95% confidence intervals for mean bird abundance 2007–08 at (1.1) active drilling (n = 3), (1.2) active pumping (n = 3), (2) abandoned (n = 5), and (3) road (n = 4) sites.

abundance in the first interval of abandoned well transects, the difference between the first and second intervals of these inactive wells was much less pronounced (x = 0.21 ± 0.62 SD versus 0.19 ± 0.10 SD) than at active sites. Road transect observations of this species were uniformly low across all intervals.

Although I observed fewer sedge wrens than meadowlarks, the distribution of sightings for the two species was similar. The initial interval of active well transects contained no sightings of sedge wrens, whereas abundance for the remaining intervals ranged from 0.00 ± 0.00 birds per transect per visit at the ninth interval to 0.25 ± 0.73 at the fifth. At abandoned well sites, wren abundance at the first interval (x = 0.16 ± 0.44 SD) was lower than at the second interval (x = 0.39 ± 0.86 SD), where abundance was greatest. However, first-interval abundance was still greater than abundance at 6 out of 10 abandoned well intervals.

Observations of other species at active well sites were fairly even across all intervals, and savannah sparrows were actually sighted more times in the first 2 intervals than at any others.

**Noise Monitoring**

At all sites, background noise from the ocean was generally in the range of 32–53 dB, depending on distance from the ocean and wind direction. In addition to noise from oil and gas extraction activity, Coast Guard planes and other aircraft occasionally flew over my transects during surveys, generating noise readings of up to 54 dB.
Noise levels at the starting point of my transects ranged from values in the 30 dB range at abandoned sites distant from the ocean to a maximum of >80 dB at active sites oil and gas extraction activity, Coast Guard planes and other aircraft occasionally flew over my transects during surveys, generating noise readings of up to 54 dB.

Noise levels at the starting point of my transects ranged from values in the 30 dB range at abandoned sites distant from the ocean to a maximum of >80 dB at active sites undergoing drilling (Table 6). Noise levels at the 0-, 150-, and 300-m intervals were significantly higher ($P = 0.000$) at active wells than at either abandoned wells or roads

Table 4. Mean abundance (birds/transect/visit) of target species for each distance interval at active, abandoned, and road sites, 2007–08. Target species are savannah sparrow, grasshopper sparrow, Le Conte's sparrow, sedge wren, American pipit, yellow-rumped warbler, and meadowlark, plus *Ammodramus* genus sparrows.

| | **Active** | | **Abandoned** | | **Road** | |
|---|---|---|---|---|---|---|
| **Interval** | **Mean ± SE** | **95% CI** | **Mean ± SE** | **95% CI** | **Mean ± SE** | **95% CI** |
| **1 (0–30m)** | 1.18 ± 1.82 | 0.54–1.81 | 1.79 ± 2.58 | 0.94-2.64 | 1.00 ± 1.79 | 0.05-1.95 |
| **2 (30–60m)** | 2.85 ± 2.51 | 1.98–3.73 | 2.21 ± 2.45 | 1.40-3.01 | 1.75 ± 2.05 | 0.66-2.84 |
| **3 (60–90m)** | 2.03 ± 2.02 | 1.32–2.74 | 2.05 ± 2.60 | 1.20-2.90 | 1.00 ± 1.15 | 0.38-1.62 |
| **4 (90–120m)** | 2.24 ± 2.18 | 1.48–2.99 | 2.16 ± 1.95 | 1.51-2.80 | 1.44 ± 1.71 | 0.53-2.35 |
| **5 (120–150m)** | 2.2 ± 2.03 | 1.50–2.91 | 2.74 ± 3.65 | 1.54-3.94 | 1.69 ± 1.35 | 0.97-2.40 |
| **6 (150–180m)** | 1.82 ± 1.60 | 1.26–2.38 | 3.45 ± 5.09 | 1.78-5.12 | 2.69 ± 1.74 | 1.76-3.61 |
| **7 (180–210m)** | 2.09 ± 2.18 | 1.33–2.85 | 2.24 ± 2.26 | 1.49-3.00 | 2.44 ± 2.68 | 1.01-3.87 |
| **8 (210–240m)** | 2.15 ± 2.42 | 1.29–3.01 | 2.62 ± 2.91 | 1.65-3.59 | 2.12 ± 2.70 | 0.68-3.57 |
| **9 (240–270m)** | 1.1 ± 1.66 | 0.49–1.71 | 2.09 ± 2.5 | 1.20-2.98 | 2.75 ± 2.79 | 1.26-4.24 |
| **10 (270–300m)** | 2.68 ± 3.94 | 1.23–4.12 | 2.69 ± 2.79 | 1.68-3.89 | 3.88 ± 3.79 | 1.85-5.9 |

Table 5. Mean abundance (birds/transect/visit) plus or minus standard error (SE) of target species at distance intervals 1–10 at active, abandoned, and road sites. Target species are savannah sparrow (SAVS), grasshopper sparrow (GRSP), Le Conte's sparrow (LCSP), sedge wren (SEWR), American pipit (AMPI), yellow-rumped warbler (YRWA), and meadowlark (MEAD), plus *Ammodramus* genus sparrows (AMMO).

| **1 (0–30m)** | **SAVS** | **GRSP** | **LCSP** | **AMMO** | **YRWA** | **SEWR** | **AMPI** | **MEAD** |
|---|---|---|---|---|---|---|---|---|
| Active | 1.94±5.59 | 0.11±0.40 | 0.08±0.28 | 0.03±0.16 | 0.43±1.5 | 0.00±0.00 | 0.00±0.00 | 0.31±0.79 |
| Abandoned | 1.24±1.94 | 0.10±0.51 | 0.03±0.16 | 0.00±0.00 | 0.05±9.23 | 0.15±0.44 | 0.00±0.00 | 0.21±0.62 |
| Road | 0.38±1.5 | 0.13±0.34 | 0.13±0.34 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.12±0.34 |
| **2 (30–60m)** | | | | | | | | |
| Active | 1.46±1.54 | 0.22±0.48 | 0.03±0.17 | 0.03±0.16 | 0.25±1.00 | 0.06±0.23 | 0.00±0.00 | 0.58±1.42 |
| Abandoned | 1.39±1.82 | 0.03±0.16 | 0.05±0.32 | 0.03±0.16 | 0.00±0.00 | 0.39±0.86 | 0.00±0.00 | 0.19±0.40 |
| Road | 0.75±0.93 | 0.31±0.70 | 0.19±0.40 | 0.00±0.00 | 0.00±0.00 | 0.19±0.54 | 0.00±0.00 | 0.18±0.54 |
| **3 (60–90m)** | | | | | | | | |
| Active | 1.28±1.79 | 0.08±0.37 | 0.11±0.32 | 0.00±0.00 | 0.00±0.00 | 0.03±0.17 | 0.06±0.23 | 0.44±0.84 |
| Abandoned | 1.34±2.22 | 0.05±0.23 | 0.13±0.34 | 0.13±0.34 | 0.00±0.00 | 0.21±0.53 | 0.00±0.00 | 0.26±0.72 |
| Road | 0.56±1.09 | 0.00±0.00 | 0.06±0.25 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.06±0.25 | 0.25±0.58 |
| **4 (90–120m)** | | | | | | | | |
| Active | 1.17±1.46 | 0.06±0.23 | 0.08±0.28 | 0.08±0.28 | 0.00±0.00 | 0.08±0.28 | 0.00±0.00 | 0.72±1.39 |
| Abandoned | 1.39±1.55 | 0.05±0.23 | 0.05±0.23 | 0.05±0.32 | 0.10±0.46 | 0.13±0.41 | 0.05±0.23 | 0.29±0.56 |
| Road | 0.56±1.03 | 0.00±0.00 | 0.31±0.60 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.06±0.25 | 0.31±0.48 |
| **5 (120–150m)** | | | | | | | | |
| Active | 1.28±2.42 | 0.03±0.17 | 0.08±0.28 | 0.19±0.47 | 0.06±0.25 | 0.25±0.73 | 0.00±0.00 | 0.56±1.08 |
| Abandoned | 1.63±2.82 | 0.00±0.00 | 0.05±0.32 | 0.05±0.32 | 0.10±0.46 | 0.16±0.44 | 0.00±0.00 | 0.53±1.11 |
| Road | 0.94±0.93 | 0.06±0.25 | 0.06±0.25 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.06±0.25 | 0.25±0.68 |

Table 5. Continued.

| 6 (150–180m) | SAVS | GRSP | LCSP | AMMO | YRWA | SEWR | AMPI | MEAD |
|---|---|---|---|---|---|---|---|---|
| Active | 1.03±1.56 | 0.03±0.17 | 0.11±0.32 | 0.03±0.17 | 0.00±0.00 | 0.11±0.32 | 0.03±0.17 | 0.42±0.65 |
| Abandoned | 2.29±5.01 | 0.05±0.23 | 0.10±0.31 | 0.03±0.16 | 0.05±0.23 | 0.08±0.36 | 0.00±0.00 | 0.76±1.15 |
| Road | 1.38±1.31 | 0.25±0.45 | 0.00±0.00 | 0.06±0.25 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.81±1.05 |
| **7 (180–210m)** | | | | | | | | |
| Active | 1.03±1.32 | 0.03±0.17 | 0.06±0.23 | 0.06±0.23 | 0.00±0.00 | 0.19±0.58 | 0.00±0.00 | 0.64±0.99 |
| Abandoned | 1.24±1.62 | 0.08±0.36 | 0.05±0.23 | 0.02±0.16 | 0.00±0.00 | 0.10±0.31 | 0.00±0.00 | 0.45±0.80 |
| Road | 1.44±2.48 | 0.06±0.25 | 0.12±0.34 | 0.06±0.25 | 0.00±0.00 | 0.12±0.34 | 0.00±0.00 | 0.50±0.89 |
| **8 (210–240m)** | | | | | | | | |
| Active | 1.14±2.00 | 0.03±0.17 | 0.06±0.23 | 0.22±0.59 | 0.00±0.00 | 0.11±0.32 | 0.11±0.40 | 0.50±1.21 |
| Abandoned | 1.39±1.73 | 0.03±0.16 | 0.13±0.41 | 0.00±0.00 | 0.00±0.00 | 0.10±0.31 | 0.05±0.23 | 0.74±1.03 |
| Road | 1.12±1.67 | 0.38±0.50 | 0.06±0.25 | 0.06±0.25 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.50±1.31 |
| **9 (240–270m)** | | | | | | | | |
| Active | 0.66±1.64 | 0.08±0.37 | 0.03±0.17 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.03±0.17 | 0.47±1.16 |
| Abandoned | 1.05±1.94 | 0.13±0.47 | 0.05±0.23 | 0.05±0.23 | 0.05±0.23 | 0.05±0.23 | 0.3±0.16 | 0.21±0.47 |
| Road | 1.38±1.93 | 0.12±0.34 | 0.19±0.54 | 0.00±0.00 | 0.00±0.00 | 0.06±0.25 | 0.00±0.00 | 0.62±1.41 |
| **10 (270–300m)** | | | | | | | | |
| Active | 1.37±3.06 | 0.00±0.00 | 0.14±0.49 | 0.08±0.37 | 0.00±0.00 | 0.08±0.28 | 0.03±0.17 | 0.64±0.96 |
| Abandoned | 1.21±1.93 | 0.08±0.27 | 0.03±0.16 | 0.00±0.00 | 0.00±0.00 | 0.13±0.53 | 0.05±0.23 | 0.63±1.00 |
| Road | 2.81±4.09 | 0.12±0.34 | 0.06±0.25 | 0.02±0.16 | 0.00±0.00 | 0.12±0.34 | 0.00±0.00 | 0.31±0.87 |

(Figure 7). However, noise levels at the end of active transects declined to an average of 48 dB as compared to approximately 46 dB at the end of both abandoned and well transects.

When active wells were broken down into pumping wells and actively drilling sites, the active site types were both significantly different at the 0-m interval from each other and from abandoned and road sites (Table 7, Figure 8). At both 150 and 300 m, drilling wells were still significantly louder than all other site types, none of which showed any significant difference.

**Vegetation Characteristics**

Over both study years, neither litter depth nor maximum vegetation height exhibited any linear trend with distance from the center of disturbance at active, inactive, or road sites (Figures 9–14). However, maximum vegetation height was noticeably lower at the 0-m interval of active sites than at all other points along the transect at which measurements were taken. Maximum vegetation height at the first measuring interval was on average 30% lower than at the next interval. This was also 9% lower than the next-lowest maximum height, which occurred at 150 m from active pads.

In 2007, the average maximum vegetation height (Table 8) for each of the 3 site types ranged between 0.49 m and 0.52 m and did not differ significantly among types ($P = 0.200$). Litter depth (Table 8) was also similar among site types and showed no significant differences ($P = 0.170$), with average litter depth among the 3 types differing by ≤1 cm.

In 2008, however, maximum vegetation height (Table 8) differed significantly among the 3 site types, with vegetation at abandoned sites being on average 14% taller than at active sites and 11% taller than at road sites. Active sites had the lowest maximum vegetation height ($x = 0.53$ m) and abandoned sites had the highest ($x = 0.64$ m). Vegetation height at active sites was significantly different from that at abandoned sites ($P = 0.000$), as was also the case for abandoned and road sites ($P = 0.003$). Active and road sites were not significantly different ($P = 0.101$). Litter depth (Table 8)

Table 6. Maximum, minimum, and mean noise readings in decibels (dB) for drilling, pumping, abandoned, and road site types, 2007–2008.

| **Site Type** | **Maximum (dB)** | **Minimum (dB)** | **Mean (dB) ± SE** | ***n*** |
|---|---|---|---|---|
| **Active (drill)** | | | | 3 |
| 0m | 84 | 50 | 64 ± 1.01 | |
| 150m | 73 | 43 | 56 ± 1.12 | |
| 300m | 69 | 41 | 52 ± 1.00 | |
| **Active (pump)** | | | | 3 |
| 0m | 72 | 31 | 52 ± 1.01 | |
| 150m | 66 | 29 | 46 ± 0.68 | |
| 300m | 65 | 32 | 46 ± 0.68 | |
| **Abandoned** | | | | 5 |
| 0m | 60 | 30 | 45 ± 0.54 | |
| 150m | 60 | 30 | 45 ± 0.53 | |
| 300m | 62 | 33 | 46 ± 0.51 | |
| **Road** | | | | 4 |
| 0m | 69 | 34 | 47 ± 0.82 | |
| 150m | 63 | 30 | 46 ± 0.84 | |
| 300m | 59 | 32 | 46 ± 0.75 | |

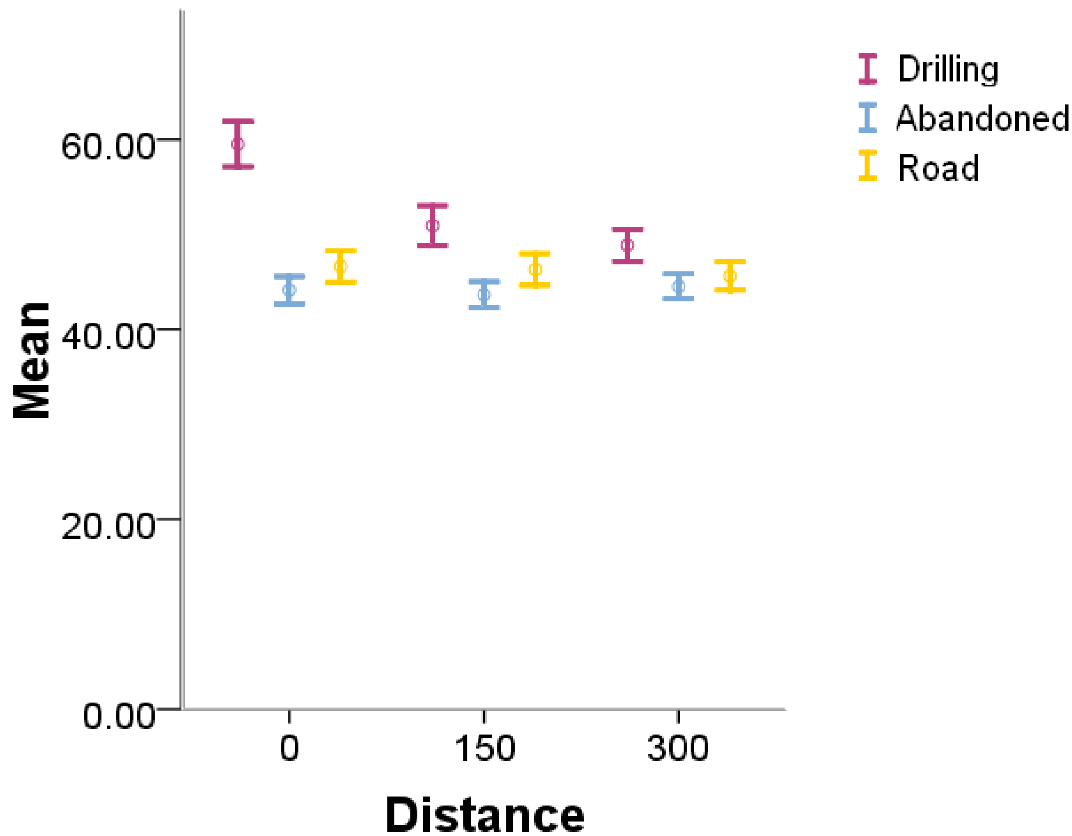



Figure 7. 95% confidence intervals for mean noise at 0, 150, and 300 m from the edge of each of 3 site types. 1 = active (n = 5), 2 = abandoned (n = 5), and 3 = road (n = 4) sites.

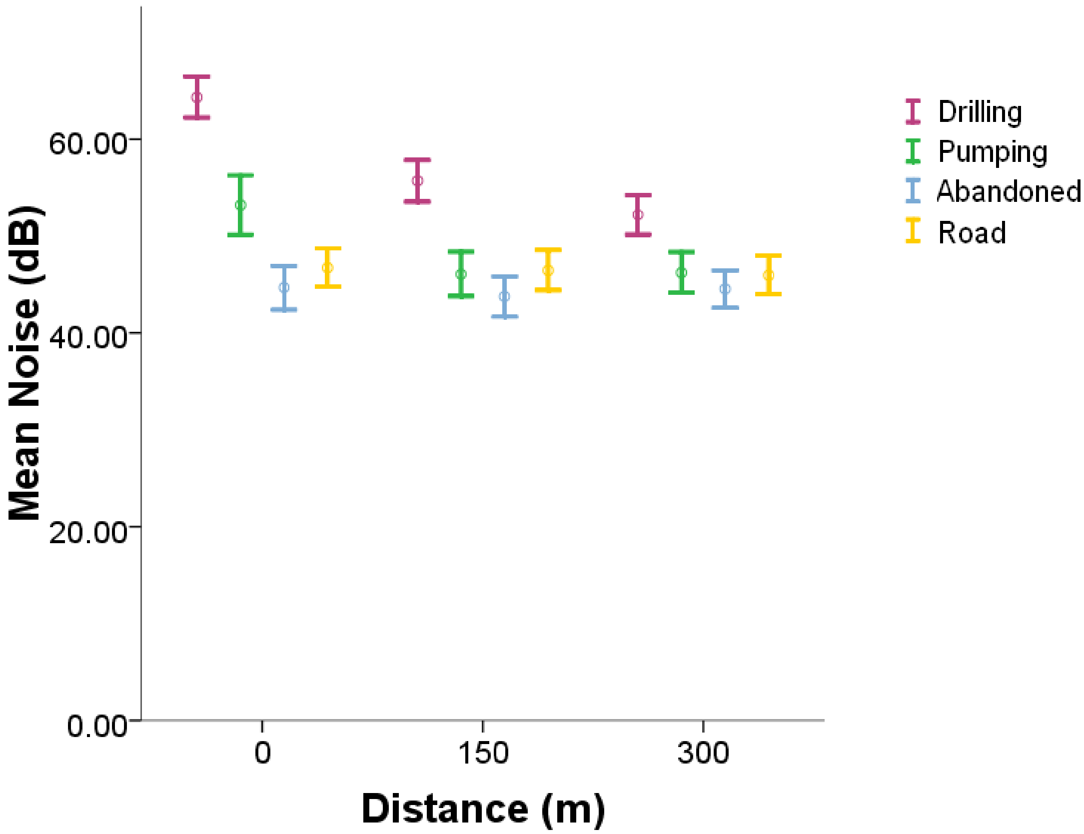



Figure 8. 95% confidence intervals for mean noise at 0, 150, and 300 m from the edge of each of 4 site types. 1.1 = active drilling well pad ($n$ = 3), 1.2 = active pumping well pad ($n$ = 3), 2 = abandoned well site ($n$ = 5), and 3 = road site ($n$ = 4).

Table 7. Mean noise levels in decibels (dB) plus or minus standard error (SE) at 0, 150, and 300 m from the center of each of 4 site types.

| | Active (drill) | | Active (pump) | | Abandoned | | Road | |
|---|---|---|---|---|---|---|---|---|
| **Distance** | **Mean** | **95% CI** | **Mean** | **95% CI** | **Mean** | **95% CI** | **Mean** | **95% CI** |
| **0m** | 64.2 ± 7.0 | 62.2–66.3 | 52.3 ± 9.0 | 50.6–54.1 | 45.2 ± 6.9 | 44.2–46.3 | 46.6 ± 7.1 | 45.0–48.3 |
| **150m** | 55.7 ± 7.7 | 53.5–56.0 | 47.2 ± 7.2 | 45.8–48.6 | 45.1 ± 6.8 | 44.0–46.1 | 46.3 ± 7.2 | 44.6–48.0 |
| **300m** | 51.1 ± 10.2 | 48.1–54.1 | 46.8 ± 7.2 | 45.4–48.2 | 45.7 ± 6.5 | 44.7–47.1 | 45.6 ± 6.5 | 44.1–47.1 |

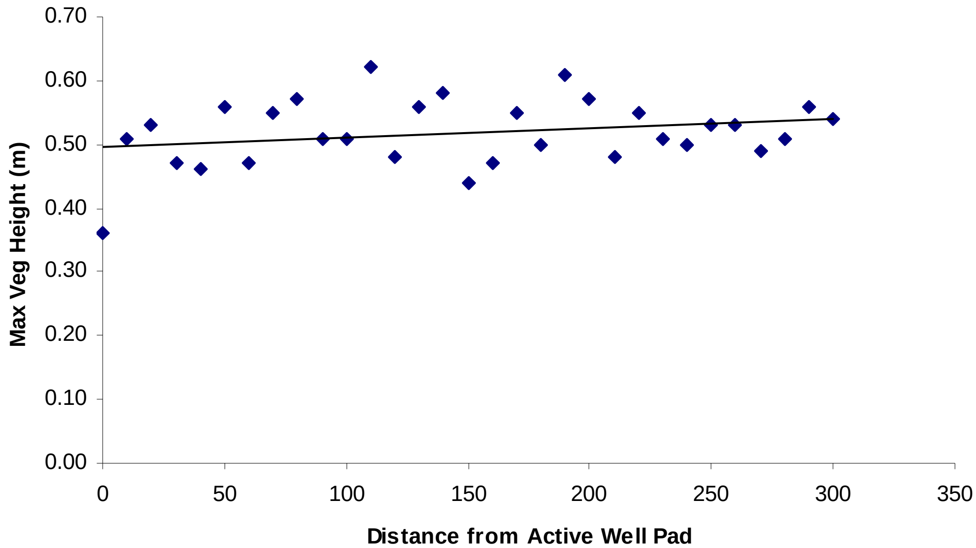



Figure 9. Mean maximum vegetation height (m) with increasing distance from edge of active well pads, 2007–08 ($R^2 = 0.015$, $P = 0.515$).

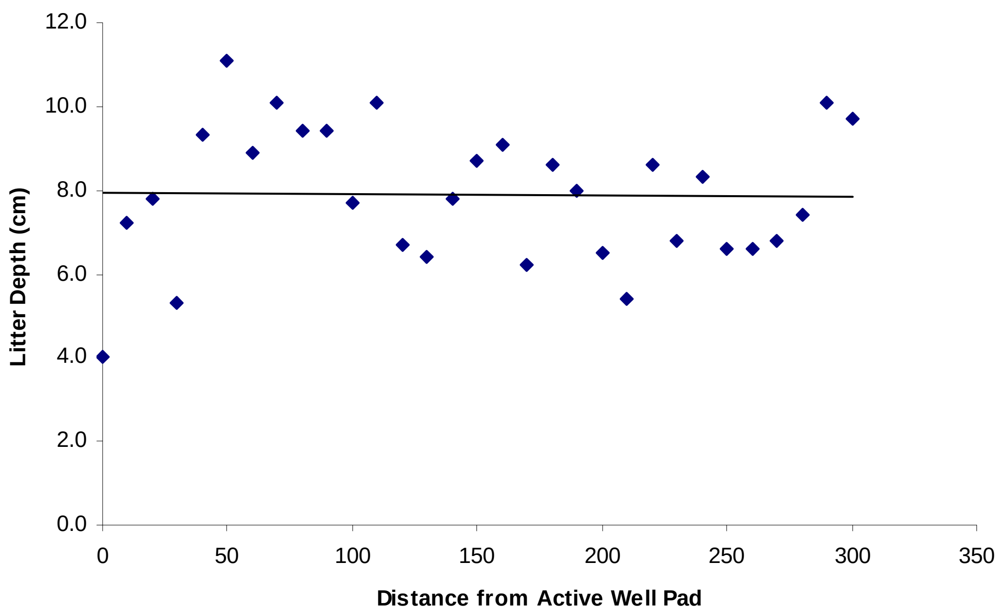



Figure 10. Mean litter depth (cm) with increasing distance from edge of active well pads, 2007–08 ($R^2 = 0.073$, $P = 0.142$).

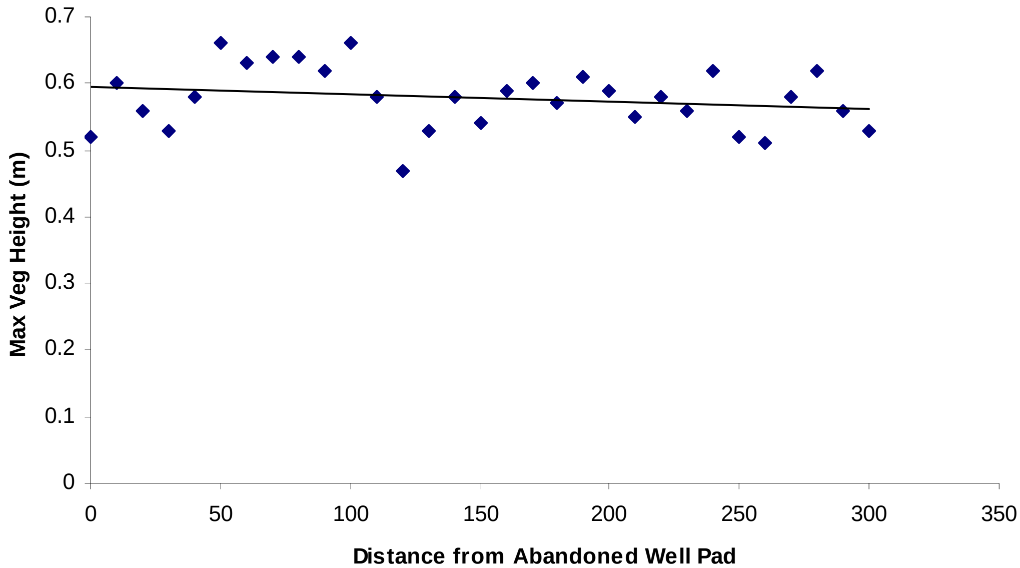



Figure 11. Mean maximum vegetation height (m) with increasing distance from edge of abandoned well pads, 2007–08 ($R^2 = 0.041$, $P = 0.277$).

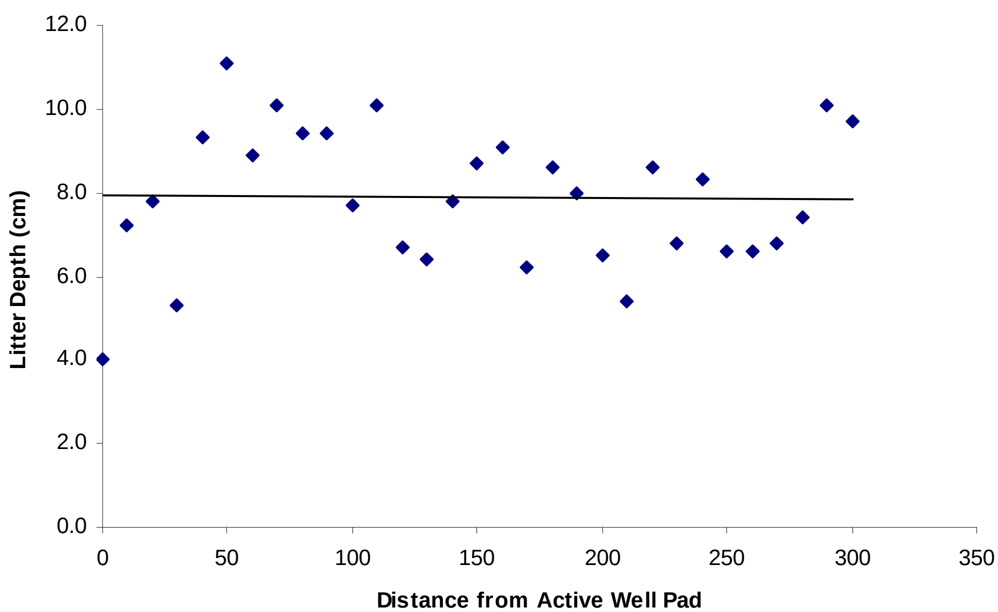



Figure 12. Mean litter depth (cm) with increasing distance from edge of abandoned well pads, 2007–08 ($R^2 = 0.004$, $P = 0.737$).

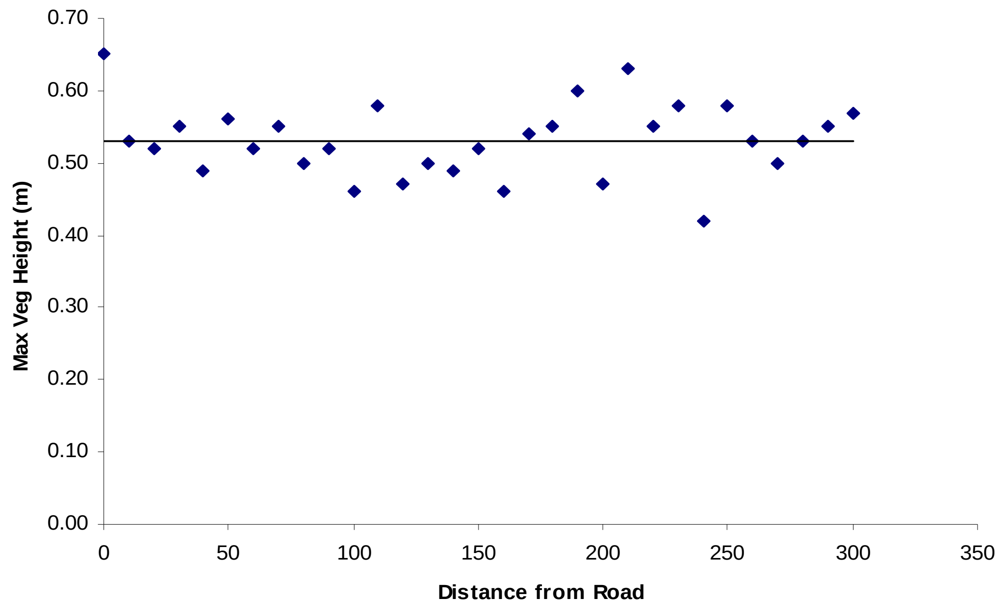



Figure 13. Mean maximum vegetation height (m) with increasing distance from edge of roads, 2007–08 ($R^2 = 0.00$, $P = 0.994$).

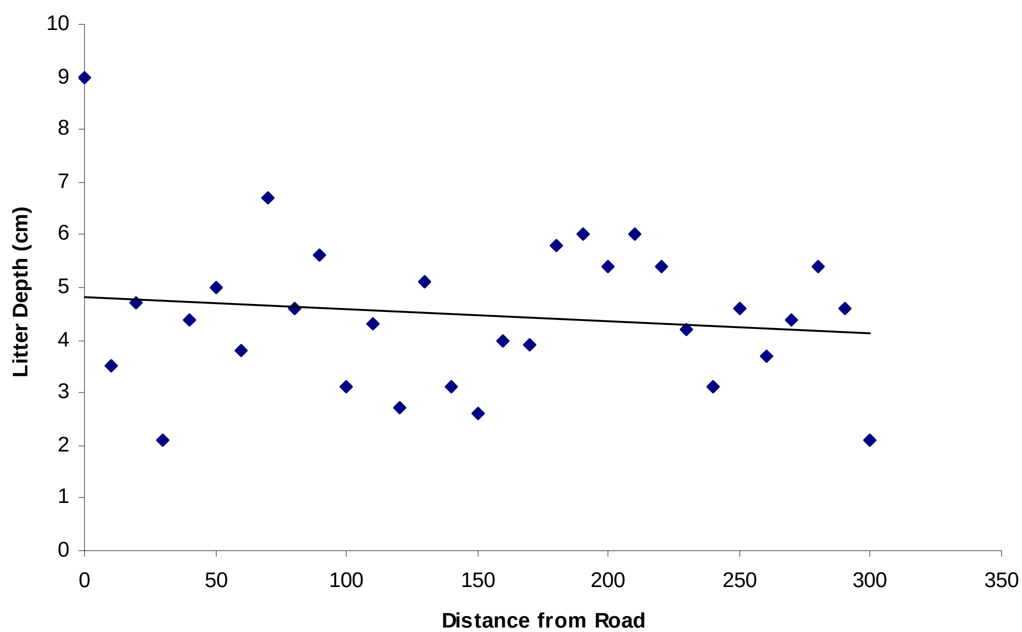



Figure 14. Mean litter depth (cm) with increasing distance from edge of roads, 2007–08 ($R^2 = 0.020$, $P = 0.452$).

similarly differed among all site types in 2008. Litter differed significantly between active and abandoned sites, active and road sites, and abandoned and road sites (*P* = 0.000 for all). Abandoned sites had the highest litter depths (x = 11.5 cm) of all site types, followed by active sites (x = 7.1 cm) and roads (x = 4.6 cm). Thus litter at abandoned sites was 39% deeper than at active sites and 60% deeper than at road sites.

Percent litter cover differed significantly between 2007 and 2008 at active and abandoned well sites (*P* = 0.000 for both), as did percent bare ground (*P* = 0.023 for active sites and *P* = 0.001 for abandoned sites). At both types of well sites, litter cover was nearly twice as great in 2008 as in 2007. Percent litter cover at road sites showed a much smaller and non-significant difference between study years, being only 7% greater in 2008 than 2007. This was largely because some sites in 2007 were partially flooded, which consequently reduced both litter cover and bare ground of the affected transects. The smaller difference seen between study seasons at road sites is explained by the fact that most of the road transects occupied higher ground and were dry both years. Percent grass (*P* = 0.273) and percent forb cover (*P* = 0.547) were unaffected by temporary flooding and were not significantly different between years for any site type (Tables 9 and 10).

In 2007, none of the 5 cover variables differed significantly among site types (Table 9). In 2008, percent litter cover and percent bare ground at road sites were significantly different from both well site types, with road sites having 24% less litter cover than active sites and 35% less than abandoned sites (Table 10). Percent litter cover was 0.74 ± 0.18 (95% CI 0.65–0.83) at active sites and 0.86 ± 0.14 (95% CI 0.78–0.93) at abandoned sites and was not statistically significant among the 2 well site types. Percent grass cover and percent forb cover showed no significant differences among any of the 3 site types.

Table 8. Maximum vegetation height (m) and litter depth (cm) for active, abandoned, and road transects, 2007–2008.

| | Active | | Abandoned | | Road | |
|---|---|---|---|---|---|---|
| | **Mean+SD** | **95% CI** | **Mean+SD** | **95% CI** | **Mean+SD** | **95% CI** |
| **2007** | | | | | | |
| **Max Veg Height (m)** | 0.49±0.24 | 0.47–0.51 | 0.52±0.24 | 0.50–0.54 | 0.49±0.20 | 0.47–0.52 |
| **Litter Depth (cm)** | 4.0±7.4 | 3.3–4.6 | 4.8±7.6 | 4.2–5.5 | 4.2±7.0 | 3.4–5.1 |
| **2008** | | | | | | |
| **Max Veg Height (m)** | 0.53±0.12 | 0.48–0.57 | 0.64±0.07 | 0.61–0.66 | 0.56±0.08 | 0.53–0.60 |
| **Litter Depth (cm)** | 7.1±2.1 | 6.3–7.8 | 11.5±2.8 | 10.5–12.5 | 4.6±2.1 | 3.9–5.4 |

Table 9. Percent cover values for active, abandoned, and road transects in 2007.

| **2007** | **Active** | | **Abandoned** | | **Road** | |
|---|---|---|---|---|---|---|
| **% Cover** | **Mean±SD** | **95% CI** | **Mean±SD** | **95% CI** | **Mean±SD** | **95% CI** |
| Grass | 0.88±0.09 | 0.82–0.94 | 0.90±0.13 | 0.83–0.96 | 0.92±0.09 | 0.84–0.99 |
| Forb | 0.19±0.17 | 0.08–0.30 | 0.19±0.13 | 0.13–0.26 | 0.15±0.10 | 0.07–0.23 |
| Litter | 0.42±0.21 | 0.29–0.55 | 0.47±0.31 | 0.32–0.62 | 0.44±0.35 | 0.14–0.73 |
| Water | 0.12±0.17 | 0.01–0.23 | 0.05±0.09 | 0.00–0.09 | 0.09±0.17 | -0.06–0.23 |
| Bare Ground | 0.46±0.27 | 0.29–0.63 | 0.48±0.35 | 0.32–0.65 | 0.48±0.39 | 0.15–0.80 |

Table 10. Percent cover values for active, abandoned, and road transects in 2008.

| **2008** | **Active** | | **Abandoned** | | **Road** | |
|---|---|---|---|---|---|---|
| **% Cover** | **Mean±SD** | **95% CI** | **Mean±SD** | **95% CI** | **Mean±SD** | **95% CI** |
| Grass | 0.83±0.13 | 0.77–0.89 | 0.93±0.11 | 0.87–0.99 | 0.95±0.11 | 0.85–0.93 |
| Forb | 0.15±0.15 | 0.08–0.22 | 0.10±0.08 | 0.05–0.14 | 0.09±0.11 | 0.00–0.18 |
| Litter | 0.74±0.18 | 0.65–0.83 | 0.86±0.14 | 0.78–0.93 | 0.51±0.26 | 0.29–0.73 |
| Bare Ground | 0.26±0.19 | 0.17–0.36 | 0.14±0.14 | 0.07–0.22 | 0.49±0.26 | 0.27–0.71 |

## DISCUSSION

I found little difference in avian abundance among the three site types, although other research has suggested that birds are often negatively affected by noise and human activity on their breeding grounds (e.g. Veen 1973, Reijnan et al. 1996). In fact, active wells had slightly higher numbers of birds than abandoned wells, and passerine diversity was highest along access road transects. Birds seemed to occupy sites with little regard to overall noise and activity levels, suggesting that other features of the landscape were more important factors. Many birds that I observed close to active well sites were perched on stakes, posts, and other artificial structures associated with the wells, while a small mesquite tree growing within 90 m of the Dunn-Peach 2 well often contained several savannah sparrows and yellow-rumped warblers as well as mourning doves. In these cases perch sites, which were otherwise rare features across the island, appeared to be an attraction that surpassed any possible disturbance from the wells near which they were located.

Birds may also have frequented active well sites simply because characteristics of the vegetation were more favorable there than at abandoned wells and road sites. Vegetation height was significantly taller and litter significantly deeper at abandoned sites than at active and road sites, which may have reduced the utility of the abandoned sites to some bird species. Many grassland sparrows, including grasshopper and savannah, cannot forage effectively in places where vegetation and litter are too dense and instead tend to occupy more open grasslands (e.g., Wiens 1969, Whitmore 1981). This preference for areas with lower litter depths and less dense vegetation may help to account for the lack of effect that proximity to an active well pad had on most species in my study. Maximum vegetation height was noticeably lower at the 0-m interval of active sites than at all other points along the transect at which measurements were taken, being on average 30% lower than at the next interval. This may have been attractive to bird species typically inhabiting more open areas, especially given that noise and activity did not appear to be correlated with any patterns of either increased or decreased abundance for most birds.

The sedge wren and eastern meadowlark, however, were sighted in lower numbers at the first (0–30m) interval of active well sites than at any other distance interval along active transects. Meadowlarks were almost two times less abundant (47%) at the interval closest to active wells than they were at the next (30–60m) interval; abundance was also 27% lower at the first interval than at the next-lowest interval. One outstanding difference between meadowlarks and the other species in my study is that the meadowlarks were the only birds that frequently sang throughout both study seasons. Nearly all singing birds that I sighted during my study were perched on either tall vegetation or on an elevated prominence such as an old dune. The lack of tall vegetation immediately next to active well pads may have meant that adequate singing perches were not available for meadowlarks and could have discouraged their presence. Previous studies in similar areas, such as one conducted on loggerhead shrikes on nearby Matagorda Island (Chavez-Ramirez et al. 1994), have indicated the importance of nonwoody vegetation as perches for grassland species. It seems likely that lack of grassy vegetation of a sufficient height could contribute to lower numbers of certain species which commonly use such vegetation as perch sites.

The high noise levels (≤84 dB) at active well pads may have also deterred meadowlarks from occupying the interval closest to the pad. As research has extensively shown, birds use both songs and call notes for a variety of social functions, including mate selection and display, pair bond formation, territory defense, foraging, and flock formation and cohesion (e.g., Knight 1974, Kroodsma 2004, Catchpole and Slater 2008). As a result, anything that interferes with the ability of birds to hear and differentiate among songs and calls may have a significantly detrimental effect. The meadowlarks in my study may have been more sensitive to noise and disturbance simply because they invested more time vocalizing during the winter than did any other species. While a few other species, most notably savannah sparrows, called frequently throughout the winter, these vocalizations seemed to be used most often within flocks of sparrows that were in close proximity to each other. As a result, high noise levels may have been less detrimental to the sparrows' ability to communicate than they were for meadowlarks.

The distance at which sound gradually disappears, or attenuates, varies with the type of environment in which a certain bird is found. The rate of attenuation is greater in open environments such as grasslands than in areas of thick, layered vegetation such as woodlands (Marten and Marler 1977). The height at which a bird perches to sing or call also affects sound attenuation, with sounds from higher perches generally having a greater range and slower attenuation than sounds from lower perches. Thus it is possible that the low vegetation heights might have acted together with high noise levels to create an environment especially unsuited to singing birds.

Not all birds are equally affected by noise and human activity, and certain species may be more sensitive to disturbance from human activity than others. For instance, Burger (1981) showed that jogging as well as mowing disturbed herons, egrets, and to some degree ducks, while having little effect on gulls and terns. Another study showed that breeding and juvenile goshawks (*Accipiter gentiles*) living 500 m from a logging road appeared to experience no ill effects from the sporadic noise of traffic, which occurred at a frequency of 80 Hz and reached a maximum of about 50 dB (Grubb et al. 1998). Previous research suggests that meadowlarks are among these more sensitive species, with studies such as that by Miller et al. (2001) showing that western meadowlarks (*Sturnella neglecta*) exposed to pedestrian traffic consistently flushed at greater distances than either other target species, the vesper sparrow (*Poecetes graminius*) and the American robin (*Turdus migratorius*). Eastern meadowlarks are thought to be quite sensitive to human disturbances during the breeding season and may even abandon their nests if people approach them too closely (Lanyon 1995). This species-based variation in sensitivity may account for the lack of response seen in most of my target bird species as compared to meadowlarks.

The potential response of birds to high levels of noise may go beyond their response to the average level of background noise at a site. Peaks of more intense noise occurring at irregular intervals, such as the spikes of noise up to 84 dB at active sites in my study, or in other studies such disturbances as aircraft flyovers (Conomy et al. 1998, Delaney et al. 1999) or chainsaws (Delaney et al. 1999), can also provoke a negative reaction in nearby birds. Such reactions could be something as simple as orienting towards the noise or a startle response (Delaney et al. 1999). Another study by Ellis (1981) showed that noise created by aircraft overflights was associated with increased heart rates in prairie falcons, and while this response lasted ≤ 5 min, the more frequent noise fluctuations associated with drilling wells at my sites could potentially contribute to numerous periods of physiological stress in meadowlarks and other birds throughout the day. Periodic spikes in noise levels occurring at irregular intervals might also be more difficult for birds to habituate to than to constant background noise only a few decibels lower in intensity. Additionally, these higher peaks of noise generated sporadically may reach some threshold beyond which even less sensitive birds are affected, just as there is a threshold of noise intensity at which sounds become first an irritant to people and then actually harmful (e.g., Mato and Mufuruki 1999). Because spikes in noise levels did occur irregularly, the chances of observing bird responses to any particular spike in intensity were low and would likely not be adequately represented in my data.

With the exception of the first distance band, overall bird abundance at both active and abandoned wells was fairly constant from most to least disturbed areas along transects and showed no clear linear trends. Along road transects, however, bird abundance clearly increased with distance from the road. It is unclear why such a trend should have existed near roads and not near active wells, where noise and activity levels were much higher and occurred far more constantly than along roads. This trend occurred independently of variations in either grass height or litter depth, neither of which showed any clear distance-related patterns. While this pattern seems unusual in light of the results from active well pads, previous research has shown that this is not an unusual trend in itself. Numerous studies (e.g., Reijnan et al. 1987, Reijnan and Foppen 1994) indicate that numbers of breeding birds may be depressed within moderate distances (≤500m) of busy highways. These researchers (Reijnan et al. 1996) found that even on a road with only moderate traffic loads (5,000 cars/day), 7 out of 12 bird species experienced a decline of 12-56% with 100 m of the road, while 2 species, black-tailed godwit (*Limosa limosa*) and oystercatcher (*Tringa tetanus*), showed a negative effect as far as 500 m away. In general, oil and gas access roads do not even approach such high traffic volumes as the roadways in these studies. However, some birds will avoid even rural roads with low traffic volumes up to a distance of some 500–600 m (Veen 1973). A study performed on a low-traffic (407–459 vehicles/day) road in the Chihuahuan Desert found that 21 of 26 species declined in abundance with proximity to the road, and that species richness was also lower close to the road (Gutzwiller and Barrow 2003). The results of 3 different studies by Reijnan et al. (1995, 1996) also showed that some passerines are highly sensitive even to relatively quiet sounds, with songbird population densities decreasing at an average noise level of 42 dB for forest birds and 48 dB for grassland birds.

It seems possible that the intermittent nature of the disturbance along the Pan-Am road (i.e., heavy but sporadic road traffic) was enough to disturb nearby birds but was not constant enough to allow them to habituate to the noise or activity. Most studies suggest that birds can become habituated even to intermittent noises such as aircraft flyovers, but again, not all species respond to such disturbance in the same way or adapt equally well. For example, in a study by Conomy et al. (1998), black ducks (*Anas rubripes*) kept in an aviary became acclimated to the sound of actual or simulated jet aircraft noise, while wood ducks (*Aix sponsa*) never habituated to the noise. Birds at Padre Island may be accustomed to a relatively high level of background noise (≤56 dB) due to the ocean and wind, but be more disturbed by noises that are loud yet only occur sporadically. During my study period I noted very few loud but intermittent noises, which aside from access road traffic came entirely in the form of aircraft flyovers.

In addition to the sporadic activity of the roads, taller and thicker vegetation immediately adjacent to the road edge may have been less suitable to ground-foraging birds than more open areas farther away. Average litter depth near the road edge was 9 cm, while it was only 3.5 cm at 10 m from the road and was never greater than 6.7 cm at any other point along the road transects. Similarly, maximum vegetation height averaged higher at the road edge than along the rest of the transects. The taller vegetation and deeper litter close to road margins may be explained by the fact that road dust often contains nutrients such as calcium and phosphorous, which could have fostered the growth of nearby grasses if lack of these nutrients was a limiting factor in plant growth (Farmer 1993).

These vegetation patterns are the opposite of those seen at active well sites, where lower vegetation and shallower litter corresponded to bird abundances comparable to or higher than that recorded at other points along the transects at which vegetation was higher and litter deeper. However, this alone cannot account for the pattern of bird abundance seen along road transects, as abundance continues to increase with distance despite the fact that beyond the edge of the road vegetation height and litter depth remain fairly constant.

Although vegetation height was significantly taller and litter significantly deeper at abandoned sites than at active and road sites, I believe that these differences were due more to site topography and burn activity than to disturbance from resource extraction. Unsurprisingly, grass tended to be tallest and litter deepest in portions of the park where no burning had occurred for several years, such as the abandoned Sun B-4 and Coral well sites. These sites were also located in wetter lowland areas nearer the interior of the island, where the vegetation was likewise taller and thicker than in places closer to the dune line.

Active wells, on the other hand, were more likely to be situated close to the dunes for easy access or to occupy higher areas of the interior island, most likely to provide good drainage for the well pad area. The Pan-Am road, the access road where 3 of my 4 road transects was placed, also passed mostly through drier, slightly more elevated areas and was in most places only a few hundred meters from the dune line. The good drainage of these road and well sites, combined with the presence of large mud flats near the two Dunn-Peach wells, can probably explain most of the variation in vegetation in litter among site types.

Though well pads represented a major and obvious impact, vegetation structure and composition did not seem to be affected much beyond the pads themselves. Vegetation height and litter depth were relatively uniform along the length of all transects and showed no linear relationship with distance from pads or roads. While vegetation was often somewhat trampled and sparse immediately adjacent to the well pad perimeter, this disturbance was usually confined to the very edge of the pad and was never continuous around the entire perimeter. Similarly, although road sites tended to have taller vegetation and deeper litter very close to the road margin, these differences evaporated within 10 m.

The fact that I was unable to locate more than 4 abandoned well sites out of ≥51 may in itself be a testament to the resiliency of the vegetation and topography of Padre Island and other barrier islands like it. The dynamic action of wind and water in continually shaping the island’s landscape, especially during the violent storms that occur every several years, ensure that most traces of human activity are obliterated over a relatively short span of time (Carls et al. 1995).

Of my 4 inactive sites, only 2 showed obvious signs of previous extraction activity in the form of the remains of the compact caliche well pad and abandoned pumping equipment and debris. The third could only be located by the presence of a small pond formed by the removal of buried tanks, and of the last pad only small patches of bare caliche remained which could hardly be distinguished from the surrounding area. The rapidly changing nature of the island may help flora and fauna alike to recover from disturbance more quickly than in other places where any disturbance can be observed on the landscape for years to come.

## CONCLUSIONS AND MANAGEMENT IMPLICATIONS

It appeared that impacts on birds and vegetation from oil and gas extraction during my study were minimal. Because only 2 of 7 target species showed reduced abundance at active wells and their abundance was only depressed within 30 m of active well sites, this suggests that the greatest impact from drilling and pumping is confined to a small area immediately surrounding well pads. Former well sites, despite some remaining traces in the form of leftover caliche, debris, and soil compaction, showed good vegetation recovery and were difficult to distinguish from other parts of the landscape.

On the other hand, despite the fact that negative impacts are moderate and relatively localized, the fact remains that the grasslands of PAIS are an essential refuge for wintering birds in a region where the vast majority of native coastal prairie tracts have been lost or severely fragmented due to agriculture and the expansion of urban areas. When the amount of suitable habitat available to these birds is already so restricted, preserving the quality of the little remaining prairie wherever it is found becomes especially vital. Additionally, with the number of oil and gas operations in the park only expected to increase in the next few years, these small impacts could easily grow into a larger and more widespread one as more wells and pumping stations are installed across the island.

The impacts from the creation of new wells are further compounded by the construction of new access roads and the extension of existing ones. Unless wells are sited very close to the dune line, their installation will inevitably involve the construction of miles of access road, with their potential to disrupt water flows, alter plant growth, and depress bird abundance being extended for long distances across the interior grasslands of the park. Because of their length and the distance outward to which they appear to affect avian abundance, these roads could represent a fairly heavy impact on grassland bird populations in the park. For example, the longest access road in the park, the Pan Am road, runs for a distance of some 8 km through the grasslands before ending along a mud flat. With its impact extending at least 300 m out from its margins, this would indicate ~240,000 m² of affected grassland for this road alone. Additionally, Carls et al. (1987) estimated a total area of >28,000 m² taken up by the road itself, which would bring the total impacted area to ~268,000 m² for 1 access road.

Access roads thus represent a complicated problem not only in that proximity to them is associated with a distinct decline in bird abundance, but also because they are extensive and permanent features of the park as long as resource extraction continues. When combined with their potentially very large area of effect, such factors may make them one of the most significant impacts of resource extraction. Further research on road impacts in the park might help identify the factors responsible for declines in abundance and mitigation measures might ultimately be taken to limit the roads' effects, but in the meantime it seems that access roads will continue to have significant impacts upon any grassland areas they pass through.

The fact that the species most heavily affected by oil and gas development, the meadowlark, is a year-round resident of the park should make the impacts of such development an even stronger concern. This is especially true given that meadowlarks are thought to be very sensitive to human disturbances during the breeding season. Like those of most other grassland birds, meadowlark populations have declined throughout much of their range, so any detrimental impacts of resource extraction on either their winter or year-round habitat must be of some concern. Other permanent residents of PAIS might also be similarly affected during the breeding season when territorial and mating displays, and thus perches and quieter sites, take on greater importance.

Based on my findings, the following recommendations may prove helpful in maintaining bird abundance and preserving the island's native vegetation:

1. Reduce noise at active sites. Requiring installation of mufflers on compression equipment will help reduce noise levels at pumping sites. While noise levels and impacts on birds may be higher at drill sites, these disturbances are relatively short-lived, whereas pumping stations may be in place for several years.

2. Make all efforts to ensure that disturbance to grasses and other plants does not extend beyond well pads and road edges. This includes trampling of vegetation, compaction of soil by foot and vehicle traffic, burial of vegetation by dirt and debris generated by pad and road construction, and pollution from spills of hydrocarbons and other pollutants. All can alter vegetation composition and structure close to sites and thus affect bird abundance as well.
3. Preserve perch sites. While there are currently park regulations to protect the largest trees on the island, further initiatives should take into account all trees and shrubs that might be removed or harmed in the course of pad and road construction and other activity associated with drilling and well maintenance. Limiting disturbance to vegetation near well pads and roads will help to protect tall grasses that are also used as perches.
4. Continue regulations for site rehabilitation by resource extraction outfits. The stricter regulations passed in the past decade, which have placed responsibility for site recovery on oil and gas companies upon plugging of wells, appear to have been very successful where supervision has ensured compliance. Most abandoned wells can no longer be located even with aerial photos, suggesting that recovery has been nearly complete.
5. Limit construction of new roads wherever possible. Until impacts from access roads are better understood, restricting the number and length of new roads may help protect grassland birds.

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# APPENDIX A

## GEOGRAPHICAL COORDINATES OF OIL AND GAS SITES SURVEYED AT PADRE ISLAND NATIONAL SEASHORE, 2007–2008.

Table A-1. Latitude and longitude for all study sites used during 2007–2008. Center points for wells were usually obtained from the NPS or Carls et al. (1987) and were used to initially locate some active wells or abandoned sites; as such they do not necessarily represent the exact center of the site. Center points for roads represent the true point along each access roads from which transects were laid. Transects did not always follow strict cardinal directions but are referred to by the approximate direction in which they extended.

| Site | Latitude/Longitude |
|---|---|
| **Active Wells** | |
| ***Sprint (formerly Amoco #1)*** | |
| Center | 27° 20' 01.0" N<br>97° 20' 04.0" W |
| North | 27° 20' 04.1" N<br>97° 20' 05.3" W |
| East | 27° 20' 03.1" N<br>97° 20' 03.4" W |
| South | 27° 20' 01.7" N<br>97° 20' 07.2" W |
| West | 27° 20' 03.3" N<br>97° 20' 07.0" W |
| ***Wilson #1*** | |
| North | 27° 28' 09.0" N<br>97° 16' 56.5" W |
| East | 27° 28' 38.0" N<br>97° 16' 36.6" W |
| South | 27° 28' 03.9" N |

Table A-1. Continued.

| Site | Latitude/Longitude |
|---|---|
| **Active Wells, continued** | |
| ***Wilson #1, continued*** | |
| West | 27° 28' 06.9" N<br>97° 16' 58.0" W |
| ***Dunn-Peach #1*** | |
| North | 27° 17' 13.4" N<br>97° 21' 52.9" W |
| East | 27° 17' 11.9" N<br>97° 21' 52.4" W |
| South | 27° 17' 11.0" N<br>97° 21' 53.2" W |
| West | 27° 17' 11.4" N<br>97° 21' 54.1" W |
| ***Dunn-Peach #2*** | |
| North | 27° 17' 58.9" N<br>97° 21' 23.9" W |
| East | 27° 17' 55.8" N<br>97° 21' 21.47' W |
| South | 27° 17' 54.8" N<br>97° 21' 21.9" W |
| West | 27° 17' 58.0" N<br>97° 21' 25.2" W |
| ***Lemon-Lemonseed*** | |
| Center | 27° 14' 19.4" N<br>97° 21' 36.2" W |
| North | 27° 14' 20.6" N<br>97° 21' 36.5" W |

Table A-1. Continued.

| Site | Latitude/Longitude |
|---|---|
| **Active Wells, continued** | |
| ***Lemon-Lemonseed, continued*** | |
| East | missing |
| South | 27° 14' 18.5" N<br>97° 21' 39.7" W |
| West | 27° 14' 21.1" N<br>97° 21' 39.5" W |
| **Abandoned Wells** | |
| ***Carrl #4*** | |
| Center | 27° 12' 54.0" N<br>97° 21' 59.0" W |
| North | 27° 12' 53.7" N<br>97° 21' 57.5" W |
| East | 27° 12' 53.3" N<br>97° 21' 58.1" W |
| South | 27° 12' 53.2" N<br>97° 21' 58.5" W |
| West | 27° 12' 53.6" N<br>97° 21' 58.6" W |
| ***Coral #1*** | |
| Center | 27° 21' 46.0" N<br>97° 19' 31.0" W |
| North | 27° 21' 46.9" N<br>97° 19' 30.6" W |
| East | 27° 21' 46.3" N<br>97° 19' 31.1" W |

Table A-1. Continued.

| Site | Latitude/Longitude |
|---|---|
| **Abandoned Wells, continued** | |
| ***Coral #1, continued*** | |
| South | 27° 21' 46.3" N<br>97° 19' 31.7" W |
| West | 27° 21' 46.4" N<br>97° 19' 31.4" W |
| ***Louis-Dreyfuss*** | |
| North | 27° 12' 21.8" N<br>97° 22' 33.5" W |
| East | missing |
| West | missing |
| ***Sun B-4*** | |
| Center | 27° 31' 12.0" N<br>97° 16' 21.0" W |
| North | 27° 31' 13.1" N<br>97° 16' 21.5" W |
| East | 27° 31' 12.5" N<br>97° 16' 21.0" W |
| South | 27° 31' 12.4" N<br>97° 16' 21.8" W |
| West | 27° 31' 13.1" N<br>97° 16' 21.5" W |
| **Access Roads** | |
| ***Pan Am, Site 1*** | |
| Center | 27° 18' 31.4" N<br>97° 20' 42.2" W |
| ***Pan Am, Site 2*** | |
| Center | 27° 18' 05.4" N<br>97° 20' 57.0" W |

Table A-1. Continued.

| Site | Latitude/Longitude |
|---|---|
| **Access Roads, continued** | |
| ***Pan Am, Site 3*** | |
| Center | 27° 18' 54.7" N<br>97° 20' 29.4" W |
| ***Wilson Road*** | |
| Center | missing |

# VITA

Ardath L. Lawson received her Bachelor of Science degree in wildlife and fisheries sciences from Texas A&M University at College Station in 2004. She entered the Wildlife and Fisheries Sciences graduate program at Texas A&M University in September 2005 and received her Master of Science degree in August 2009. Her research interests include avian population biology and behavior, and the ecology and preservation of the threatened Cross Timbers ecotype. She plans to pursue a degree in museum science following the completion of her M.S.

Ms. Lawson may be reached at Texas A&M University, Department of Wildlife and Fisheries Sciences, 210 Nagle Hall, 2258 TAMU, College Station, TX, 77843-2258. Her email is Ardath6@aol.com.